HOUSE ORGAN OF Q-ALLOYS "To Be Sure" GENERAL ALLOYS COMPANY

ALLOY PROGRESS

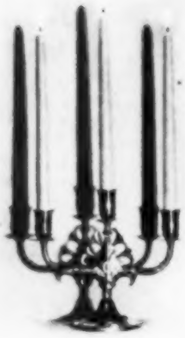
EDITED BY H. H. Harris PRESIDENT

Bright Spot in Metal Progress

ENTIRELY ABOUT HEAT & CORROSION RESISTANT ALLOY CASTINGS

Vol. 4 Number 2

LOYALTY • MENTALITY • VITALITY



Abstract of President's New Year's letter to General Alloys Employees, written after January Alloy Progress had gone to press.

ALL my life I have burned candles at but three shrines, LOYALTY, MENTALITY, VITALITY.

Tonight, on the eve of a New Year, three candles burn brightly at General Alloys, symbolic not of my idyllic concept of foundation and revelation, inspiration and reward, but of the very essence of this organization.

LOYALTY, to those who depend upon us, and to those on whom we depend.

MENTALITY, that we may plan wisely, devise ingeniously, judge fairly.

VITALITY, that we may plow deeply, seed painstakingly, harvest in abundance.

In short, we strive to be a straight shooting outfit, with BRAINS enough to find the Target, and GUTS enough to pull the trigger.

General Alloys has been in the black since 1932, with vision undimmed—ambition fortified by technical progress. We kept our organization intact, carried on research, and technical development.

Most important is that we did not pollute our own well. General Alloys made no inferior grades, and no General Alloys salesman prostituted his company to meet "Cheap" or panic competition.

The fact that our products were standard equipment with 85% of all furnace builders, before price competition made the furnace builder conscious that he only guaranteed his furnace one year, and could get by with cheaper alloy, stands as FACT.

Now that Operating Economy, not first cost, is again in vogue, users and Furnace Builders will expect improved alloy mechanisms, *and get them*, not from the punks who nuzzled the P.A. through the depression, but from the one alloy organization who, having built more alloy mechanism than all competitors combined, should know something about it.

EXPERIENCE is the best foundation for any program. General Alloys Program for 1937 is: BETTER ALLOYS. VASTLY IMPROVED MECHANISM. TECHNICAL ADVANCEMENT that will rout "price" competition as the sun of Prosperity melts the slush of depression.

GENERAL ALLOYS IS ON THE MARCH, re-dedicating our Loyalty, Mentality and Vitality to those Ideals of Quality and Service which have maintained the unquestioned Leadership of an Industry.

H. H. Harris

Pleasant environment stimulates genius, as does Lithia Water properly alloyed. (38-18 is a proven proportion.) The prominent Gentlemen, stars of the Surface Combustion All-American Furnace Team, shown in the conference room of the Wm. Penn, Pittsburgh, were chosen by Miss Bourke-White, Ace Photographer, to symbolize Prosperity, in LIFE, to whom we are indebted for this picture. The Right Guard, studying the next play, is Al. Hollinger.

An 8x10 print of Skyview above will be sent gratis on request to any member of A.S.M. whose Company operates a heat-treat, or manufactures heat-treating supplies or equipment.

No furnace is better than its Alloy Parts

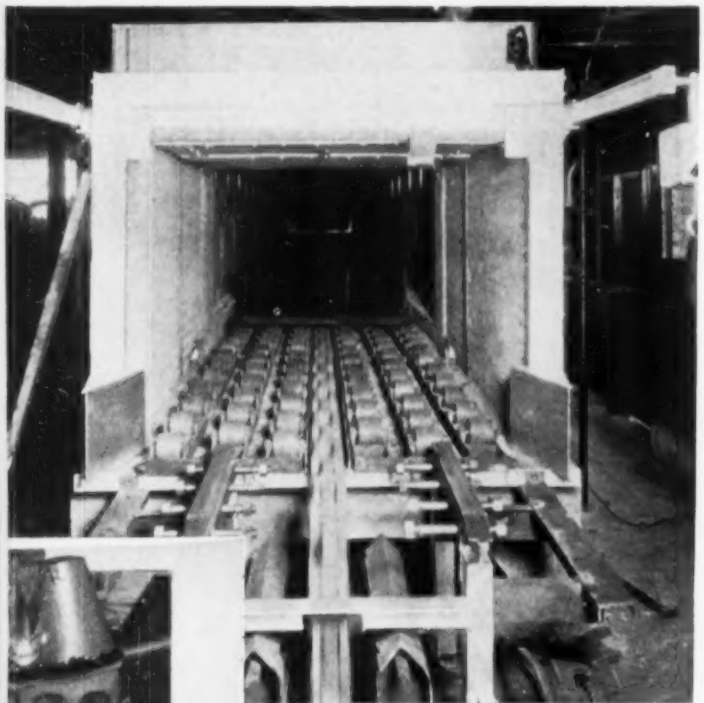

Year's Eve Candied Shots of Prominent Steel Treaters

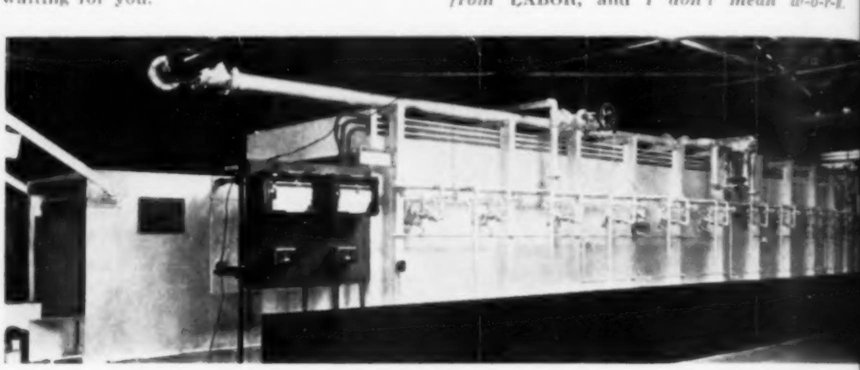
FROM WHERE I SIT ~ BY H. H. HARRIS

EVERYBODY knows that the depression didn't get the A.S.M. down. Pilot Bill Eisenman brought the old ship into port with a deckload of Government Bonds and a disgustingly rotund surplus, while we Steel Treaters generally were counting our marbles. One swallow may not make a summer, but it often makes a spender, thus the first swig of Prosperity has sent the team into action. Twenty-eight touchdowns were recorded in the last game of the 1936 season, scored in Hostelries, Clubs and Honkey-Tonks across the Nation. At ringsides everywhere were Q-Alloy Candid Cameramen, and shutters clicked as 1936 took the count. If your picture is in this issue, write in for your Jigger-whack. It's waiting for you.

OUR new SPIRALINK conveyor furnace is going great guns. Westinghouse, Swindell and Surface Combustion have sold furnaces built around the Spiralink belt. Leading Furnace Builders are keen for improved alloy mechanisms, and General Alloys are leading this field as never before.

PROSPERITY is back in a big way, so strong, in places, you can smell it. You could smell it in Detroit in the G.O. Days, —but now it reeks. Those Motor Men who Graduated from Gisholts to Grosse Pointe in one grunt were just pikers of the Hossless Buggy Days. Just Panty-Waists. You should see the New Crop Rich! Big Money from *Industry??* That's *old stuff;*—now, the Real Money comes *from* LABOR, and *I don't mean w-o-r-k.*





SURFACE COMBUSTION FURNACE

Surface Combustion Engineers have made outstanding progress in Annealing and Controlled Atmosphere Furnaces, obsoleting older types, offering economies that cannot be ignored by cost conscious operators, particularly when combined with marked quality improvement.

Above is a continuous Pan Type Annealing Furnace used to anneal brass in sheets and coils, installed in 1936. The pans rest on X-ite rollers mounted on X-ite Rails. They are pulled through the furnace by an X-ite chain. All Alloy Mechanism by General Alloys Company, who have supplied alloy for hundreds of Surface Combustion Furnaces over a period of 10 years, exceeding guarantees at least 200%.

No competitor has a remotely comparable alloy service record, either with Surface Combustion or any other furnace builder.

OPERATING DATA:

Fuel—Gas, 530 B.T.U.

Temperature of Furnace, 1200° F.

Average Rockwell Hardness, 70

Total Time of Test, 2.833 hours

Conveyor Speed, 1.61 feet per minute

Total Net Work Annealed, 31,270 pounds

Total Gross Work Annealed, 38,770 pounds

Total gas consumption, 15,000 cubic feet

Net Work annealed per hour, 11,060 pounds

Gross work annealed per hour, 13,710 pounds

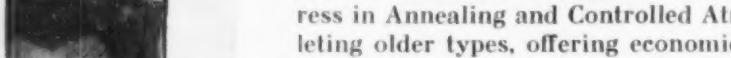
Gas consumption per hour, 5,295 cubic feet

Gas consumption per pound net, 0.479 cubic feet

Gas consumption per pound gross, 0.386 cubic feet

Net thermal efficiency, 35.6%

Gross thermal efficiency, 46.6%


your picture is on this page you get a jigger whack

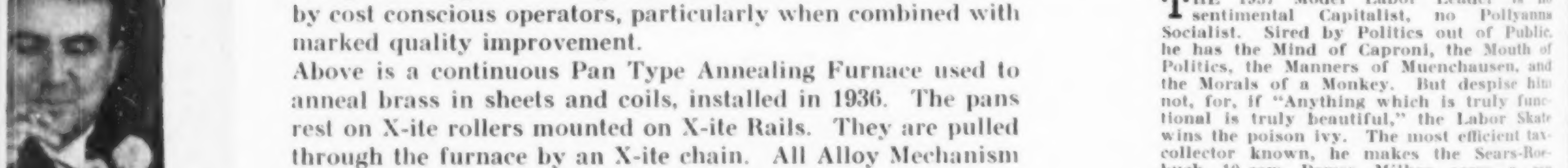
POOL, Merger, Syndicate, Consolidation, mere transitory media, just maggots on a milestone in the evolution of the *perfect Formula* for Power & Privilege. *That Formula is: EXPLOIT LABOR.* Its Master: the self anointed would-be "Representative" of your Employees.

THE 1937 Model Labor Leader is no sentimental Capitalist, no Pollyanna Socialist. Sired by Politics out of Public, he has the Mind of Caproni, the Mouth of Politics, the Manners of Muenchausen, and the Morals of a Monkey. But despise him not, for, if "Anything which is truly functional is truly beautiful," the Labor Skate wins the poison ivy. The most efficient tax-collector known, he makes the Sears-Roebuck 10-cow Power Milker seem a cog *request.*

IF Religion is "Opium for the Masses," Labor Racketeering is a "Mickey-Finn" for the Workers. How many Immigrant Parents, aspiring only to make pantz unmolested in Menhetten,—have begotten Labor Lawyers, sluiced through the law schools enroute from the Ghetto to the Legislature,—I do not dare contemplate, but I can imagine that the Capitalists who endowed those law schools share their mortification.

PERSONALLY, I have only one quarrel with the Princes of Labor,—they're Dam Snobs! Now that these outcrappings of Democracy are ensconced in Detroit for Collective Bludgeoning, you can't walk into the Book Casino without falling over Champagne buckets. No pikers, these birds, they ice the red wines too.

YOUTHFUL ambitions seldom carry through, possibly because they lack inspiration and perspiration. Rarely does a five year old pick a hobby and ride it for twenty-two years. In my column last month I ran pictures of a widely publicized streamline automobile built by the kid brother, B. F. H. Space did not permit inclusion of his first design and inspiration. The "design," a sketch of our 1914 chauffeur-be-damned model Cadillac. The "Inspiration," a compliment in the handwriting of the late Theodore Roosevelt, endorsed thereon during a visit at our Champaign home.



HIS "Book Casino," by the way, gripes me no end. First; because it replaced famous "Venetian" Room, and Second; ause John Belart, gracious Maitre d', departed, becoming Steward of the ess Club, thereby removing the Book's claims to distinction.

MY Friend, the late Paul Kamper, who, at thirty, designed the Book-Cadillac, ed that Venetian Room. It was his mas- piece. Architecturally and artistically nposed with subtle technique and cap- ating beauty of a great symphony, it nded with good music, superb cuisine, unobtrusive service into a delightful erience described in the jargon of ob- ete social communion as "Dining out." w, a contraption of plywood and hot- se-brick has been erected within the etian Room, obscuring every line and

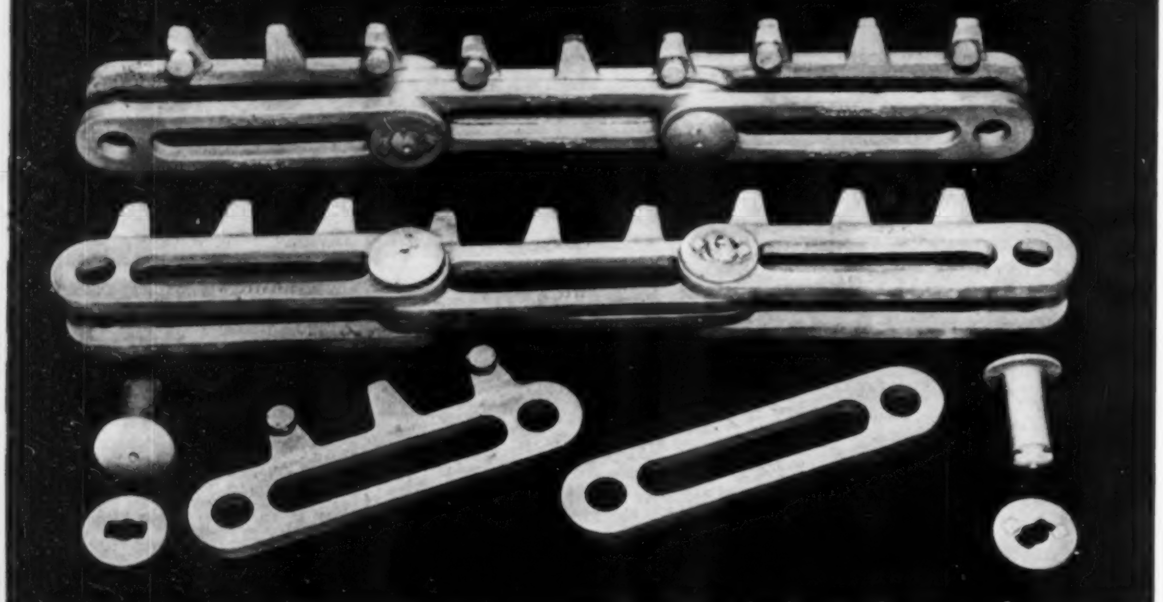
nension. The place has gone "Hitzy" ich is an alphabetic, aesthetic and tronomic retroflex from "Ritzy." With n leaving the Book and the demise of Venetian Room, the most restful and teel rendezvous in Detroit is no more. I guess I'm just getting to be an old ddy-dud,—mebbe this packing case archi- ure is kosher, and I'm wrong,—but yway, I resent being charged two "Cou- ts" on one check. I've always wanted good alibi to eat in cafeterias.

WAS flying over Chicago the other day with Bud Orne and Bud yelps "Lookit t swell number crossing the link bridge, ck, snap the kodak on that"—well, here's picture. Can you spot 'em as far away Bud? He's champion in those parts, king up infra-blonde rays at 2800 meters.

SEE the Remarkable Salem Engineering Furnace on next page. Salem could e "saved" $500 per furnace by using eap" alloy, but one breakdown would e out the saving. Not one of the 30,000 ings was X-rayed. There is no reason X-raying production heat resisting cast-

GA TWIN-LINK THE NEW IMPROVED CONVEYOR CHAIN FOR MECHANICAL FURNACES

TWIN-LINK CHAIN IS STRONGER — MORE ACCURATE — IN PITCH AND BETTER MECHANICALLY THAN OLD "SEPARABLE LINK" TYPES



Note the ingenious "Bayonet Lock" snap washer that locks in the pin — doing away with cotters or heavy "T" head sections. Many patterns with different carrier sections are available. Thousands of feet of twin-link-chain is giving 100% satisfaction.

PAT. APPLIED FOR

SALEM ENGINEERING COMPANY BUILDS AN IMPROVED MECHANICAL FURNACE

THE remarkable chain conveyor furnace shown below is doing one of the hardest mechanical furnace jobs known, heat treating "Sucker-rods" for use in the Oil Industry, and *rolling them through the furnace,* on table-flat X-ite rails.

Imagine handling red hot ½" dia. steel rods, 30 ft. long, and rolling them hot for a distance of approximately fifty feet. The eight strands of X-ite Twin-Link Chain doing that job *must all bear uniformly, or the rod would kink and not roll.* Think of a string of hundreds of castings, over a hundred feet long, *accurate to a gnat's whisker in dimension and expansion,* and you're thinking of X-ite.

Three of these super-mechanical furnaces, using over 30,000 individual X-ite castings, are functioning 100%, and more are on order, a credit to the SALEM ENGINEERING COMPANY'S policy of using first quality materials, and the best alloy mechanism obtainable.

Ed. Note: Freddy is salesman-at-large for the Porous Castings Co. Just another steel foundry philandering in the alloy business.

Dear Mr. Coldshot:

Thanks for that book "How to Handle People", but it don't work on wimmen. They should uv put out a couple feelers before publishing that. That pychological approach may sell steel, but I'm sticking to the three R's and workin' from the bottom up. Your angle on workin' from the top down is okay with your expense account, but my dice can't stand the strain. Here's the evidense Mister Coldshot, I done just what you sed and trailed them big shots into the Floosiedew Room of the Bill Penn Hotel. In this jernt yuh gotta sit down first, to buy their likker. Not high hat, just precaution. They got black table cloths, to discourage art, or mebbe they was blonde onct. Pburg is hard on blonds. One claims her popsie was a dame doggler and a gidget grabber. Just a motorman on the belt-line out skirting the town nightly. She claims he spends so much time in burlecue shows he had to buy the Womens Home Companion to find what the wimmen was wearing. Tim and me follers him to a Strip-Tease show shop, strip whoantease what, which was lousey. After the courtain we took 'em to the fights, just a couple of slug nutty punks. One knocks his versus out tonight vice versus tomorrow nite. This stuff about souses signing is the bunk, if they can't read they can't sign, and if they can read they won't sign. Anyhow did you ever learn a funnel in a Pittsburgh P.A. Even the Lady buyers is tataway in Pburg. If you don't love 'em they don't buy, and if you do love 'em they don't pay. Just big hearted girls. These two carried their big hearts behind 'em and the pair of 'em couldn't sit on the Hippodrome stage. The Pullman company had 'em run in for stealing hammocks outa their snuggle boxes. Just mistaken identity. Picked 'em up for brassieres. Febuary brides, those Pendulosa sisters, just feather babes. Reciprocity's thicker than the local cinder-juice fogs. Tim my Ape of an Ass't is working oblique on the reciprocity angle. Seems his step-brothers Newt Russ. Newt being P. A. of a rolling mill was slipped a block of deculumative Prefferred in the Goldstein Equipment Company and is writtin orders with a rubber stamp. Tim is goin' to swap stamps. You can't break through reciprocity with stogies and phone numbers. These Pittsburgh numbers is party lines anyhow. This reciprocity racket is like the dog & flea game. With one flea and one dog, it had possibilities. But the fleas got to wagging the dog. Newt says the fleas will loose Fido when prosperity turns the corner of the Bill Penn Bar and Tim and me will wait here. (See the photo.) I'm showing Tim this report and he says it's lousey.

Yours till Bradstreet's Dun,—Freddie.

P.S. I saw your phoney red headed girl friend in Erie, just comin' out of a lawyer's office, your pal, Freddie.

GENERAL ALLOYS COMPANY

367-405 W. FIRST ST., BOSTON, MASSACHUSETTS, U. S. A.

PLANTS — BOSTON, MASS. — CHAMPAIGN, ILL.

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OLDEST AND LARGEST EXCLUSIVE MANUFACTURER OF HEAT & CORROSION RESISTANT ALL…

Mosaic structure

(Continued from page 152)

As a result of the study of the intensity of reflection of X-rays by crystals, C. G. Darwin suggested that a crystal may be regarded as being composed of small crystalline fragments which are approximately parallel to each other, but whose orientations are distributed through an angular range of many minutes of arc on either side of a mean direction. All atoms within each fragment are regarded as being in perfect arrangement. Such a crystal has been termed an "ideally imperfect crystal" or "mosaic crystal."

From the experimental work it would appear that crystals are neither ideally perfect nor ideally imperfect, but have a structure which lies between the two extremes, and in most cases is much closer to the ideally imperfect. The blocks of the mosaic are smallest and show the greatest difference in orientation in the ideally imperfect type of crystal. The lower limit to the dimensions of the mosaic blocks is of the order of 5000 Å. A. B. Greninger examined single crystals of copper by means of the back reflection Laue method of X-ray analysis, and concluded that the sub-structures deviate from exact parallelism by amounts varying from 5′ or 10′ to as much as 2°. Similar conclusions as to the imperfections in crystals have been obtained by the reflections, over a range of angles, of a crystal slowly rotated in a beam of parallel X-rays.

The irregular discontinuities on which the Darwin mosaic hypothesis is based provide a simple explanation of why oxides and other alloy constituents accumulate and form veining and the sub-boundary structure of metallography. If the discontinuities inside the crystal are considered as miniature grain boundaries in which the difference in orientation between neighboring "blocks" is very small indeed, the precipitation of minute quantities of material preferentially along such "sub-boundaries" is analogous to the preferential precipitation of much greater quantities of a second phase along the crystal boundaries which characterizes the majority of two-phase alloys.

In the latter case, the presence of the constituent in a network form along the crystal boundaries is the result of pre-existing differences in lattice orientation between neighboring crystals. The presence of a second constituent in this form is sometimes of help in determining

crystal size, since the boundaries are much more easily "developed" by the etching reagent, and is also responsible for the phenomena of intercrystalline corrosion and weld decay that occur with certain alloys. Similarly, the presence of veining indicates that there are, within the crystal, pre-existing differences in orientation which, although far too small to be shown up by etching, have the effect of locating the initial precipitation of a constituent when this occurs only in a very small quantity.

In the absence of such a constituent it is considered to be quite impossible with the present technique for the microscope to detect the presence of such small orientational differences as are responsible for the mosaic structure. The position of the major inequalities in orientation within the crystal may, however, be determined by the position of the deposits concentrated in them, in the same way that a crystal boundary deposit facilitates the location of the crystal boundary. It is considered that this is the part played by the veining constituent. The absence of (visible) veining is purely negative evidence, and does not indicate the absence of the mosaic structure, whereas the presence of (visible) veining gives positive indication as to the quantity or type of the major irregularities in the crystal structure.

Perfect Mosaics Are Rare

Now, it is a common occurrence for material to be deposited upon that already precipitated, and it is probable, therefore, that although it indicates the presence of the mosaic structure, the veining gives only an incomplete picture of that structure. On the other hand, from the X-ray reflection evidence, it is known that a crystal is rarely, if ever, a perfect mosaic, but assumes some intermediate form, so that the veining network will not approach perfection. For what might be termed ideal veining, it would be necessary to have a combination of perfect mosaic structure, together with complete and regular precipitation of the veining constituent on that mosaic — conditions unlikely to be fulfilled in practice. In most instances the veining network is considerably larger than the mosaic proposed by Darwin (lower limit of the order of 5000 Å.), and this is to be expected, but there are examples where the veining network approaches this small value.

It must be remembered that the mosaic passes gradually into *(Continued on page 210)*

Mosiac structure

(Starts on page 152) the perfect crystal by the increase in size of the perfect regions until one of them occupies the whole crystal, which may then be looked upon as an ideal crystal. Heat treatment should have some effect; thus, when the veining in slowly cooled copper was compared with that in samples quenched and tempered, the veining was much more complete, more regular and the network much smaller than in the slowly cooled sample and suggested the presence of a more perfect mosaic structure. Also in copper-silicon and other alloys which had been annealed at high temperatures for a long time and very slowly cooled, the dimensions of the network were on a much larger scale than before the treatment. Conversely, air-cooled samples of different alloys showed veining which was finer and more complete than in samples very slowly cooled.

There are two other phenomena which may be included here in support of the above line of reasoning. It has been shown that in a cold-worked specimen annealed at a temperature in the neighborhood of 950° F. there was far less evidence of veining in the recrystallized areas than in those which had not recrystallized. Since the recrystallized material would have a different system of mosaic structure, there would be less reason for the veining constituent to be retained in a network form, and more reason for it to coalesce into isolated particles as actually occurred. In the same series of specimens it was observed that twinning planes appeared to spread from the position where the veining touched the new crystals. Very slight irregularities in the lattice would assist in bringing about twinning at this point.

No evidence has been found to indicate the orientation differences of the different mosaic blocks in any one crystal. Since the network structure is not revealed without the assistance of a second phase and since slip lines for the most part appear to be unaffected by veining, the orientation differences must certainly be extremely small.

A variety of mosaic structure containing a multitude of submicroscopic flaws between the perfect blocks has been postulated to explain the alleged difference between the theoretical and the observed strength of crystals. This is not a necessary assumption, for when the conditions of the experiment are so arranged that

the presence of surface cracks does not cause premature breakdown, the measured tensile strength is only slightly less than that required by theory. Likewise the properties measured in fracturing a metal that deforms plastically by slip are different than in non-ductile bodies visualized by theorists.

Nor is such an assumption necessary to explain veining. On the contrary, it is evident that the mechanical effect of a mosaic of the type under consideration is likely to be small and may be expected to operate in the direction of *increasing* the hardness and strength and reducing the plasticity or ductility, at least at atmospheric temperatures. Although the blocks of the ideal mosaic show some lattice distortion at their boundaries, this will not be sufficient to be classified as actual cracks or pores. The effect may be considered as being similar to, but on a considerably smaller scale than that exercised by crystal boundaries which are known to bring about enhanced strength in metals and alloys. Slight increases in hardness due to the network form have, in fact, been observed. Since the mechanical properties of recrystallized metals are similar to those of the materials before recrystallization, it would be expected that the mosaic should occur in one as well as in the other, and this has been shown to be so with veining structures.

An inquiry into the cause of the mosaic structure cannot, at this stage, be free from speculation, but mechanical strain during growth of salt crystals from solution or during solidification and subsequent cooling of metal crystals, may possibly be the responsible factor. The development of internal strain is a feature which frequently manifests itself in metals, but it cannot be stated whether the mosaic is associated with elastic or plastic strain. The influence of strain is shown by the tendency for a slight excess of veining to appear in quenched and tempered specimens at the junctions of three or more crystals and also by the difference in dimensions of the structures in the slowly cooled and in the quenched and tempered or air-cooled alloys.

Although complete confirmation of the association between the veining network and the pre-existing mosaic structures will be a matter of some difficulty, their dimensions and the similarity in the effects of heat treatment upon the two structures suggest some connection between them, and further work on the subject is proposed.

Help Yourself *to this* HELPFUL LITERATURE

● Insulating Brick

A new member of the Johns-Manville insulation family has been announced. It is an insulating brick, and data sheets containing particulars on characteristics and recommended uses are available. Bulletin Ba-100.

● Stress-Strain Recorder

The many applications of the Baldwin-Southwark stress-strain recorder, its unique advantages, and the many ways it can give unusual service will be extremely interesting to all who have to do with testing methods and equipment. Bulletin Ba-67.

● Hydraulic Tester

Of interest to all engineers recommending or purchasing universal testing machines is a book by Riehle Division of American Machine and Metals, Inc., on the development of the precision hydraulic testing machine. Bulletin Ba-157.

● Magnet Steels

A very handsome booklet describes the permanent magnet steels and castings made by Simonds Saw & Steel Co., including Alnico and Alnic. Bulletin Ba-158.

● Electrodes

Recommended welding procedures for the new "Shield-Arc 100" electrode as well as all other Lincoln electrodes are contained in the latest "Supplies Bulletin" published by Lincoln Electric Co. Bulletin Ba-10.

● Illuminator

An illuminator free from glare, for use with standard microscope stands, is described in a leaflet by Pfaltz & Bauer, Inc. It is known as the Reichert Epilum Illuminator. Bulletin Ba-142.

● Heat Resistance

Those who have sent for the other bulletins in Republic Steel Corp.'s series on "Republic's Perfected Stainless Steels" will not want to miss the one describing the heat resisting types, HCN, NC-3, and HC. Bulletin Ba-8.

● Stabilog

Ten outstanding advantages of the potentiometer Stabilog are fully explained in an attractively laid-out folder by the Foxboro Co. Bulletin Ba-21.

● Hard Case

A continuous breakdown test on Holden Hard Case heat treating bath is fully described and the remarkable results explained in a folder by A. F. Holden Co. Bulletin Ba-55.

● Oil Testing

An oil testing instrument catalog issued by C. J. Tagliabue Mfg. Co. should be in the hands of every oil chemist as well as all those who are interested in testing machines. An up-to-date price list is included. Bulletin Ba-62.

● Nickel Steels

A bulletin on the properties and applications of heat treated wrought nickel alloy steels will act as an invaluable aid in selecting suitable steels to meet modern industrial demands in either products or plant equipment. International Nickel Co., Inc. Bulletin Ba-45.

● Metal Surfaces

A manual giving in detail methods for the application of sodium cyanide solutions in the preparation of metal surfaces is announced by the R. & H. Chemicals Department, E. I. du Pont de Nemours & Co. Bulletin Ba-29.

● Modern Metallograph

The new Bausch & Lomb research metallographic equipment, which is arousing so much interest and favorable comment in the profession, is the subject of advance literature, recently issued. Bulletin Ba-35.

● Oxygen Lance

An eight-page booklet, profusely illustrated with diagrams and pictures, puts into convenient form much valuable information on the oxygen lance, which will be especially useful to anyone working with heavy sections of metal. The Linde Air Products Co. Bulletin Ba-63.

● Fine Steels

Compiled by men who make fine steels to assist men who use fine steels, a handy, pocket size, 150-page volume by Ludlum Steel Co. contains many new, helpful charts and tables, all made quickly available by a unique method of indexing. Bulletin Aa-94.

● Nickel Silver

Riverside Metal Co. has just published a beautiful booklet on nickel silver. If you want the latest information on this subject, presented in an attractive, interesting manner, write for Bulletin Aa-156.

● Sicromo

Timken Steel & Tube Co. has issued a new booklet on Sicromo steels which gives analyses of these new steels and discusses the effect of both silicon and chromium on oxidation resistance. Bulletin Ba-71.

● Ovens

Maehler recirculating ovens speed baking and reduce fuel costs. Why is told in a well-printed and illustrated booklet by The Paul Maehler Co. Bulletin Ba-159.

Stainless for Processing

Authoritative and complete is U. S. Steel Corp.'s well-made brochure on stainless steels for the process industries. Included in the general metallurgical information contained are a complete table of properties of USS stainless steels and a table of resistances to acids and chemicals. Bulletin Oy-79.

Heroult Furnace

A complete exposition of the Heroult electric furnace is carried through in logical style in an exceedingly handsome illustrated booklet by American Bridge Co. Salient features, types, sizes and capacities, suggestions for installation, auxiliary equipment and practical advantages are given. Bulletin Jyb-124.

Centricast Boxes

The story of centrifugally cast carburizing and annealing boxes — their reason for being, method of production, properties, and advantages — is made extremely readable in a folder by Michigan Steel Casting Co. Bulletin Jya-84.

Testing Machines

An extremely handsome, spiral-bound, segregated catalog tells all about the various hydraulic and screw power testing machines made by Tinius Olsen Testing Machine Co. Bulletin Oy-147.

Firebrick

Babcock & Wilcox make an insulating firebrick which is refractory as well as insulating and can be used without a facing of firebrick. Description, applications, and engineering data are contained in Bulletin Fy-75.

Aluminum News

A cleverly written, well-illustrated newspaper of interesting items about aluminum is issued by Aluminum Co. of America every month. The latest issue is Bulletin Jyx-54.

Silico-Manganese Steel

Silico-manganese steel for heavy springs is the subject of Bethlehem Steel Co.'s new folder giving its properties and recommendations for heat treatment. Bulletin Jyx-76.

Compressors

B. F. Sturtevant Co. has a line of centrifugal compressors designed particularly for industrial furnace applications. These are illustrated and described in Bulletin Myx-58.

Steel Shafting

Bliss & Laughlin has an attractive folder on their steel shafting, turned, drawn, ground, and polished to precision standards. Sizes and tolerances and uses are given. Bulletin Ax-42.

Sheffield Steels

Wm. Jessop & Sons, Inc., have a leaflet which tells why a special anneal and a proper balancing of carbon, manganese and tungsten combine to make Sheffield Superior oil hardening steel non-distorting and easily machinable. Bulletin Jn-61.

Nickel-Copper Steels

Exceptional resistance to corrosion and abrasion, increased tensile strength, and higher ductility are the qualities claimed for Youngstown Sheet & Tube Co.'s new series of Yoloy steels. A summary of properties and notes on their characteristics are contained in Bulletin Ox-93.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

Ni-Cr Castings

Compositions, properties, and uses of the high nickel-chromium castings made by The Electro Alloys Co. for heat, corrosion and abrasion resistance are concisely stated in a handy illustrated booklet. Bulletin Fx-32.

Heat Treating Manual

A folder of Chicago Flexible Shaft Co. contains conveniently arranged information on heat treating equipment for schools, laboratories and shops, and also illustrates the several types of Stewart industrial furnaces. Bulletin Ar-49.

Recuperators

Results obtained with Carborundum Company's recuperators using Carbofrax tubes are fuel savings, closer temperature control, faster heating, and improved furnace atmosphere. Complete engineering data are given in Bulletin Fx-57.

Stainless Data Book

All users of stainless and heat resisting alloys should find invaluable the information contained in a booklet published by Maurath, Inc. giving complete analyses of the alloys produced by the different manufacturers, along with the proper electrodes for welding each of them. Bulletin Jyb-125.

● Indicates new literature

Some of the Best Thinking

in the metal industries is at your disposal in the literature described here. One booklet may hold the key to your current problem. Help yourself to this helpful literature. It's free. You incur no obligation when you return the coupon.

Blast Cleaning

So many changes have taken place in blast cleaning and dust collecting equipment in the past three years that Pangborn Corporation's "quick reference" catalog of condensed information will be invaluable to all those interested in this subject. Bulletin Jyc-68.

Newer Tool Steels

Vulcan Crucible Steel Co. has a complete and attractive catalog listing their full line of tool steels including many special types to meet the modern trends in industry. Bulletin Jyb-127.

Testing with Monotron

Shore Instrument & Mfg. Co. offers a new bulletin on Monotron hardness testing machines which function quickly and accurately under all conditions of practice. Bulletin Je-33.

Airless Cleaning

Comprehensive coverage of abrasive cleaning and preparation methods by description and illustration is contained in a colorful book published by the American Foundry Equipment Co. It describes the airless abrasive cleaning and preparation method known as "Wheelabrating." Bulletin Dx-112.

Boiler Furnace Brick

The whole story of Crystolon (silicon carbide) brick for heavy duty use in boiler furnace walls or linings is contained, not in a nutshell, but in very compact form in a striking folder by the Norton Co. Bulletin Jyb-88.

Moly Matrix

Climax Molybdenum Co.'s little monthly newspaper contains many interesting and informative articles. Get the latest issue — Bulletin Ax-4.

Cleaning Processes

An attractive 12-page booklet entitled "Scientific Metal Cleaning" has been published by Detroit Rex Products Co. It describes in detail the applications and advantages of Detrex degreasing with Perm-A-Clor or Triad Safety Solvents and the applications of Triad Alkali Cleaning Compounds and Strippers. Bulletin Oy-111.

Kanthal

Kanthal, an alloy for electric heat developed in Sweden, is now being marketed in the United States by C. O. Jelliff Mfg. Corp. A new catalog gives full information on properties, forms available and fabrication. Bulletin Oy-78.

Hardening Furnaces

P. D. M. high speed hardening furnaces are described in two bulletins by The Philadelphia Drying Machine Co. — one devoted to oil-fired and one to gas-fired furnaces, both made in single and twin chamber models. Details of construction, design features and tables of sizes and capacities are included. Bulletin Oy-150.

Centrifugal Casting

A new circular has been prepared by the Calorizing Co. describing their methods of centrifugal casting. Bulletin Dy-26.

X-Ray Examination

The application of X-ray examination and inspection to castings, welding, and food products, as well as practical X-ray crystal analysis, is completely described and strikingly illustrated in General Electric X-Ray Corp.'s new 34-page publication. Bulletin Dy-6.

Titanium in Steel

The use of ferro-carbon-titanium in steel is thoroughly described in a booklet of Titanium Alloy Mfg. Co. Titanium's application in forgings, castings, rails, sheets and plates is interestingly explained. Bulletin M-90.

Globar Elements

Globar electrical heating units and a variety of accessories for their operation have been catalogued by Globar Division of Carborundum Co. Bulletin Oy-25.

Drawing Furnace

A new convected air gas fired furnace for drawing and tempering dense loads has been announced by Despatch Oven Co. Complete details concerning its design and operation, the results obtainable, and prices are given in Bulletin Dy-123.

Stainless Tubing

A folder full of helpful technical data on the properties and use of welded stainless steel tubing, a product finding many new applications, is offered by Carpenter Steel Co. Bulletin Oy-12.

Muffle Gas Furnaces

Two models of Juthe muffle type gas furnaces for pre-heating, hardening and annealing, and for heat treating high speed steel are described in bulletins by American Electric Furnace Co. Bulletin Aa-2.

Liquitol

The use of Liquitol for controlled cooling of iron and steel castings and ingots is fully described in a bulletin by Alpha-Lux Co., Inc. Bulletin Mya-120.

Brinell Tester

Accurate and exact measurements can be made on hard or soft materials with the Diamo-Brinell hardness testing machine, which uses a pyramid-shaped diamond instead of a steel ball. Described in a pamphlet by Pittsburgh Instrument and Machine Co. Bulletin Aa-1.

EPI Microscope

The Zeiss EPI microscope for the illumination and observation of opaque material has unlimited applications for observing opaque material in dark field, bright field, and polarized light. A descriptive leaflet is published by Carl Zeiss, Inc. Bulletin Aa-28.

Tube Furnaces

The uses, construction, control and operation of combustion tube furnaces are given in a folder by Hevi Duty Electric Co. which includes complete specifications for various types. Bulletin Aa-44.

Thermometers

A 72-page catalog by Brown Instrument Co. covers the complete line of Brown thermometers and pressure gages—indicating, recording and controlling — and enumerates the wide range of industries to which they are applicable. Bulletin Aa-3.

Coordinated Control

A new system, known as the Coordinated Control System, for automatically operating all of the technical operations and factors of an industrial process is described by the Bristol Co. Bulletin Aa-87.

Electric Heat

The certainty of results obtained with electric heat is economically available in automatically controlled electric furnaces. Hoskins Mfg. Co. has a catalog stressing the advantages and low-cost maintenance of their line of furnaces. Bulletin Jya-24.

Oven Furnaces

In a nutshell American Gas Furnace Co.'s improved oven furnaces offer controlled atmosphere, quiet operation, economy, are over and under-fired and bottom vented. Described more fully in Bulletin Aa-11.

Electric Control

A complete new control system for regulating input in proportion to demand is described in "Micromax Electric Control," an illustrated eight-page catalog issued by Leeds & Northrup Co. Bulletin Oy-46.

Liquid Carburizing

E. F. Houghton's Perliton liquid carburizer is the subject of a 23-page booklet. Depth of case, speed of penetration, and other results are well illustrated with graphs and photomicrographs. Bulletin Nv-38.

Heat in Industry

"Wherever Heat Is Used in Industry" is the title of Surface Combustion Corp.'s new booklet which starts with "Surface Combustion" principles and shows a part of various types of standard burners and furnaces and special furnaces. Bulletin Dx-51.

Electric Salt Baths

Literature is available from Bellis Heat Treating Co. describing electrically heated bath furnaces which are economical to operate and have a wide range of applications in hardening, annealing, and heat treatment of high speed steel, stainless steel, nickel, aluminum, copper and bronze, etc. Bulletin Ny-48.

Ferro-Alloys

An interesting folder by Electro Metallurgical Co. tells all about their ferro-alloys and their special service to users which will help them to operate their furnaces and make alloy additions under the proper conditions. Bulletin Jya-16.

Metal Progress,
7016 Euclid Avenue, Cleveland, O.

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Helpful Literature

(*Continued from page 213*)

Foundry Metallograph

Today's engineering cast irons are structure-controlled in the foundry. The E. Leitz simplified micrometallograph MM-2 is particularly adapted to foundry applications. Bulletin Fy-47.

Tempering Furnace

Technical details and operating data on Lindberg Steel Treating Co.'s new Cyclone electric tempering furnace, which has shown a remarkable performance record in steel treating operations, are given in Bulletin Fx-66.

Alloy Castings

Michiana Products Corp. has published a new book describing Michiana corrosion resistant and stainless steel alloys. Generously illustrated, it suggests many savings for the use of these alloys. Bulletin Oy-81.

Compressor Data

General information on the application of blowers to gas and oil burners, and miscellaneous applications for other types of work are included in a 12-page "Turbo Compressor Data Book." Useful tables and charts are included. Spencer Turbine Co. Bulletin Dy-70.

Bright Annealing

Electric Furnace Co. tells about their controlled atmosphere furnaces for continuous deoxidize annealing, bright normalizing and annealing ferrous and non-ferrous metals. Work comes clean, bright and dry from these furnaces. Bulletin No-30.

Laboratory Service

A new edition of "The Metal Analyist" tells about an organization established by Adolph I. Buehler specializing in the installation of metallurgical laboratories. The complete line of laboratory equipment marketed by Buehler is also catalogued. Bulletin Dy-135.

Specialized Tester

The Rockwell superficial hardness tester is a specialized instrument for use where the indentation into the work must be kept shallow or of small area, yet sensitivity preserved. A supplement to Wilson Mechanical Instrument Co.'s catalog on the regular Rockwell tester tells all about it. Bulletin Sy-22.

Nichrome

"Nichrome" nickel-chromium resistance alloy is not the only product made by Driver-Harris Co. A new 68-page catalog gives complete data for this well-known material as well as a wide variety of other alloys. Bulletin Oy-19.

Port Valves

Diagrams and descriptive matter show the operation of adjustable port valves made by North American Mfg. Co. that are particularly suitable for mediums whose rate of flow is not constant. Bulletin Oy-138.

Capacitrol

An indicating control pyrometer is made by Wheelco Instruments Co., known as the Wheelco Capacitrol. Their bulletin gives full description, wiring diagrams for different furnace or oven installations, and price. Bulletin Mya-110.

Pure Metals

Pure, carbide-free metals are described and applications suggested in a pamphlet published by Metal & Thermit Corp., who make pure tungsten, chromium and manganese in addition to the ferro-alloys. Bulletin Mya-64.

Cutting Oils

The problems of machine tool lubrication engendered by the high speed production and close tolerances of modern industrial operations are discussed and progress in cutting oils during the past few years reviewed in a booklet by D. A. Stuart & Co. Bulletin Jyb-118.

Corrugated Ingots

The Gathmann Engineering Co. has published a new booklet called "Gathmann Ingot Molds — Their Purpose and Design." It illustrates various corrugated ingot contours designed to produce defect-free surface in steel ingots. Bulletin Aya-13.

Forging Experience

The experience of 21 years has made National Forge and Ordnance Co. the headquarters for a host of basic electric steel products. Typical products and equipment for making them are described in a series of attractive pictorial circulars. Bulletin Dy-136.

Temper brittleness

(*Continued from page 155*) A slight increase in hardness was observed at the early stage of the first temper brittleness; we cannot, however, detect any hardness change corresponding to the second temper brittleness, even in the nickel-chromium steels which are most susceptible.

That the phenomenon is related to the quantity of existing carbide (strictly, Fe_3C with Cr or other element in solid solution) is confirmed by the tests on the first four steels in the table, of increasing chromium content. The present author's hypothesis concerning the mechanism is as follows:

Quenched steel is constituted of two phases, called simply "ferrite" and "carbide"; this ferrite in

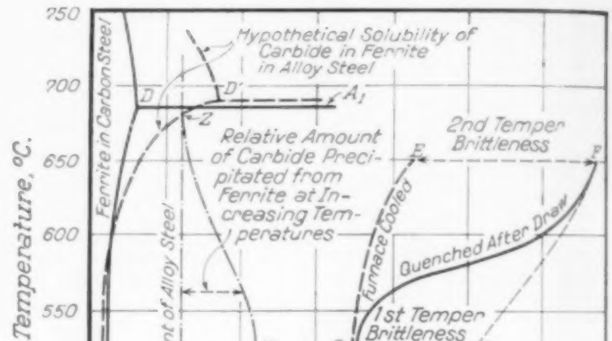


Diagram Showing How Relationship Between Drawing Temperature, Rate of Cooling, and Izod Impact (Temper Brittleness) of Typical Susceptible Steel Is Due to Carbide Precipitated From Supersaturated Ferrite

quenched steel is supersaturated with carbide which begins to precipitate on reheating at about 450° C., where sufficient atomic mobility exists to allow a movement toward equilibrium conditions. At tempering temperatures of about 525° C. all carbide is precipitated from the supersaturated ferrite that can be. Higher temperatures cause a reabsorption of some carbide in the ferrite because solubility increases above that temperature, as shown by the hypothetical line D'-N' on the equilibrium diagram for susceptible steels. (See the figure on this page.) The quantity of this precipitate existing at various temperatures in an alloy (*Continued on page 218*)

Temper brittleness

(*Starts on page 155*) steel of carbon content K is indicated by the horizontal intercepts of line X-Y-Z in the diagram (page 214).

Precipitation of this carbide between 450 and 525° C. is responsible for the first temper brittleness, and the rate of cooling after tempering is immaterial, for the solid solubility of carbide in ferrite is quite small and unchanging at these low temperatures; likewise atomic mobility is small. The amount of precipitate retained in cold steel after tempering above 525° C. depends upon the speed of cooling from the draw; quick cooling retains all that is present (not reabsorbed into ferrite as we approach line D′-N′). Higher and higher draws, followed by quenching, therefore mean lower and lower amounts of precipitated carbide in the ferrite, and greater and greater toughness. However, if the cooling after the tempering is sufficiently slow, the carbides reabsorbed above 525° C. will be reprecipitated on the way down, as their solubility relationship demands, and the resulting steel will have a maximum of precipitated carbide in the ferrite and a minimum toughness.

Experiments on samples of hardened nickel-chromium steel, quenched after long tempering at 650° C., confirm this hypothesis. They are then in the toughest condition, having almost a maximum of carbide in solution in ferrite; their Izod impact value was in fact 70 ft-lb. These pieces re-tempered at 525° F. had impact of less than 20 ft-lb., no matter how cooled. Pieces re-tempered at 650° C. and water quenched regained all of their original toughness, but if furnace cooled they were still brittle. This is a point worthy of attention when re-tempering susceptible steels.

Carbon steel is not temper brittle, because carbide is completely precipitated out of martensite below 300° C. Furthermore, the solid solubility of carbide in steel (located by line D-N on the equilibrium diagram) is very small, even at A_1 being about 0.03%. Carbides in the other non-susceptible steels are of the same nature. Molybdenum and tungsten cure temper brittleness, as can be seen by comparing the last two lines in the tabulation on page 155 with the first and third. This is perhaps due to the change in nature of the existing carbide so that the solubility curve is no longer D′-N′ on the curve on page 214 but D-N.

The second temper brittleness but not the first should be observed when tempering annealed steel, for this involves the solubility change of carbide below Ac_1. Actual experiments verified this. Chromium, manganese and phosphorus steels gained about 10 ft-lb. Izod impact when water quenched after tempering at 650° C.

METAL PROGRESS

An Editorial
on
Metallurgical Education

It has been the recent privilege of the Editor to participate in three conferences in as many technical colleges wherein the metallurgical curriculum has been scrutinized. In one of these a new department was to be organized; in the other two, courses in metallurgy had been given for many years, and it was possible to compare the required studies as of 1936, 1926, 1916, and 1906. It was unnecessary to go further back into history, because then "mining engineering" was the principal if not the only degree offered in this field, and metallurgists, assayers, mineral surveyors, geologists, petroleum engineers, merely specialized in those lines after graduation from a single but inclusive course of study.

The ruling spirit in the three above-mentioned conferences was a great conservatism, very much out of keeping with the popular conception of the bold engineer and investigator. The college developing the new course attempted to parallel its competitors; the colleges with long-established departments still were listing economic geology, or power plants, or electrical eingineering as required studies for junior or senior metallurgists. Now these are good courses for a mining engineer, who in his professional life must often rely on his own resources in isolated spots, and no one will argue that these studies are without value to any citizen, but it can be established, I think, that they are not essential to a student whose principal interest is the utilization of metals, and take up much time that could be better utilized.

A second general observation is that engineering curricula with few exceptions are still relatively fixed, almost as fixed as they were 30 years ago, in that the most of the time is occupied by a multitude of *required* studies, leaving little opportunity for electives among engineering subjects and practically none for free electives in non-engineering subjects. This is in great contrast to recent changes in liberal arts education (and even in architecture); in many prominent American universities the upperclassman has very few required studies. As he gains maturity he has a larger and larger amount of time for independent study along a definite but individual line, guided by his departmental faculty, even to the point where the senior has no requirements for graduation other than an acceptable thesis and the ability to pass a single comprehensive examination in his specialty.

One educator justified this trend in the liberal arts colleges by saying that the field of systematic knowledge has grown to be as wide as the world, and it is hopeless to set up a fixed curriculum that would embrace the reasonable desires of all the individuals comprising a numerous student body. But is this not also true of modern engineering? If a youth is to be trained to hold a certain job, a fixed series of studies and manual training exercises can be set up leading to that goal. On the other hand, if broad education as a metallurgical engineer is desired, how else can it be achieved today but by concentrating early on the fundamentals of engineering (mathematics, chemistry, physics and mechanics) and utilizing a continual and increasing amount of time for free studies in chemical metallurgy (production) and physical metallurgy (use) as the scholar's interest and ability, the resources of the college, outside industrial cooperation and other circumstances dictate?

In this rapidly changing world a fixed engineering curriculum is an anachronism. Technical colleges that hold to them must be prepared with an adequate defense. It is not much of a defense to point out that economic geology has been replaced by phase rule. While there is some danger in rushing into changes merely for the change, there is more in being so cautious that no important movement results. The liberal arts colleges are showing the way, and a great amount of prestige should accrue to the engineering college that scraps the strait-jacket curriculum and replaces it with one adapted to the times — *now*, when it is needed.

Measurements—the Data of Research

Photograph by John P. Mudd, A.R.P.S., at The Midvale Co., Philadelphia

RESEARCH — SUCCESSFUL & UNSUCCESSFUL

By Robert S. Archer
Past President, A.S.M.
Chief Metallurgist, Chicago District
Republic Steel Corp.

THE SCENE is a residential hotel in a mid-western city. The manager, whom we shall call Mr. Smith, is a very capable manager indeed, for his hotel has begun to make money in the difficult year of 1933. The United States has just left the gold standard, and Mr. Smith is fascinated by the new high price for gold. He is also very much interested in the possibility of finding new sources of gold.

Among Mr. Smith's guests is one Mr. Brown, said to be a mining engineer. Mr. Smith and Mr. Brown become quite well acquainted, and it develops that some 25 years ago Brown was employed by a great American mining corporation, was sent into the heart of Siberia to get the real facts about a certain mining property, but was discharged and blacklisted for refusing to falsify his report at the request of certain dishonest executives of his employing firm. Thereafter he was unable to find further employment in his profession anywhere in the United States.

So to Mexico where, although he did not get back into mining, Brown did become acquainted with Pancho Villa. In fact, Senor Villa was so impressed with Mr. Brown's capabilities that he made him chief of his secret service. So Brown prospered; but all things come to an end and so did Villa.

At Torreon, in search of fortune again, Brown encountered an old friend, one of Villa's former lieutenants, whom we shall call merely the Bandit. The Bandit was very cordial, invited Brown to week-end at his sister's hacienda. After many drinks the Bandit confided to Brown that he was worth over a million dollars. Brown challenged this boast, whereupon the Bandit proudly showed a bar of gold bullion. Brown admitted that it was very nice gold — but scarcely worth a million. He had seen nothing yet, said the Bandit, and must return later.

Another week-end, more drinks, then a long ride on horseback, blindfolded, between the Bandit and another Mexican. Finally the blindfold was removed. Brown found himself in a large cave, lighted dimly but sufficiently to disclose a pile of gold bullion easily worth a million dollars. The gold had been stolen, of course. The Bandit was very anxious to turn it into money, but did not know how to do so safely. Better if the gold could be gotten out of Mexico into the States. And if Brown could accomplish this feat, he could have one half of the proceeds.

Back in the United States, Brown had a plan for getting and disposing of the gold. Unfortunately, he lacked ready cash. But do not forget that his tale greatly interested Mr. Smith, the hotel manager. Consequently, Mr. Smith staked Mr. Brown to the extent of several thousand dollars to recover the Bandit's gold.

This research did not pay!

We have in this hotel manager an example of a man, highly competent and successful in his own line of business, losing money in a field with which he was entirely unfamiliar. We may accuse him of being over-credulous, but let us remember that he could scarcely have been so with respect to his own business, or he could not have made money in 1933.

At this point it may be well to define "research," especially since we may be accused of stretching the term beyond the elastic limit to include the example just cited. The Century dictionary has, "a continued careful inquiry or investigation into a subject, in order to discover facts or principles."

Research Must Be Continued

Please note particularly three words in this definition: "Continued," "Careful," and "Discover." A single experiment or an accidental discovery does not constitute research, no matter how fortunate the outcome, because the work lacks the required continuity. The word "discover" implies that the facts or principles resulting from research must be *new*. Routine testing is not research, no matter how long continued or how carefully done, unless it is coupled with such close observation and originality of thought that new facts or principles are discovered. Research is essentially creative.

We will now concede that we stretched a point in applying the term "research" to Mr. Brown's supposed efforts to convert the Mexican Bandit's stolen gold into cash. The relationship of our hotel manager to this project, however, was similar to that of many investors or sponsors toward projects more properly designated as "research." Another true incident will illustrate this point.

Some years ago there appeared an inventor who claimed the development of a new process for the production of metallic aluminum. He did not seek money for research, because he claimed that the research was successfully completed, but for commercial exploitation. Considerable stock was sold — some of it to men who had been quite successful in their own business — but no dividends were ever paid.

In our superior wisdom we may feel that these two examples scarcely concern us. We would not be stupid enough to put money into a research project in a strange field, or at least we would not do so without consulting an expert in that field in whom we had confidence. But it happened that this particular process *was* investigated by at least one eminent and thoroughly honest chemist. He reported that he could not understand the chemistry of the process, but that he had witnessed the production of metallic aluminum. The unorthodox chemistry intrigued his curiosity, so he did not even suspect that some one might have "salted" the apparatus with metallic aluminum while the inventor and his visitors were out at lunch.

Another and more satisfying story of research in aluminum was briefly told in METAL PROGRESS (Feb. 1936) by Junius D. Edwards, about Charles M. Hall, who as a college student became engrossed in the problem. The development of Hall's process permitted drastic reductions in the price of aluminum, and thereby laid the foundation for a large industry, which turned out to be highly profitable to him and to his business associates. It is said of Hall that he worked with a clear and definite aim, and seldom became discouraged for more than a few hours at a time.

It is not necessary to consider such striking examples of profit or loss from investments in research in order to realize that these investments are sometimes profitable and sometimes unprofitable. Most of us are familiar with examples which illustrate in a less conspicuous manner that research may or may not pay.

Members Influence Research

Research in the arts and sciences relating to metals is of special interest to the American Society for Metals. Much of this work is done by our members, and the results often find expression in our publications. Furthermore, most of our members are in a position to influence the allotment of expenditures to research projects, to an extent which they may not always fully realize.

Those members who hold executive positions in the metal industries obviously have much to do with this matter. An influence which is just as real and important, although less obvious, is that exerted by every man who expresses any desire for improvement in metal products or metal-working processes. It is usually upon the cumulative evidence of demand resulting from such expressions that executives base their appropriations for research. Whenever any member of our Society asks a manufacturer of metal products, or of equipment,

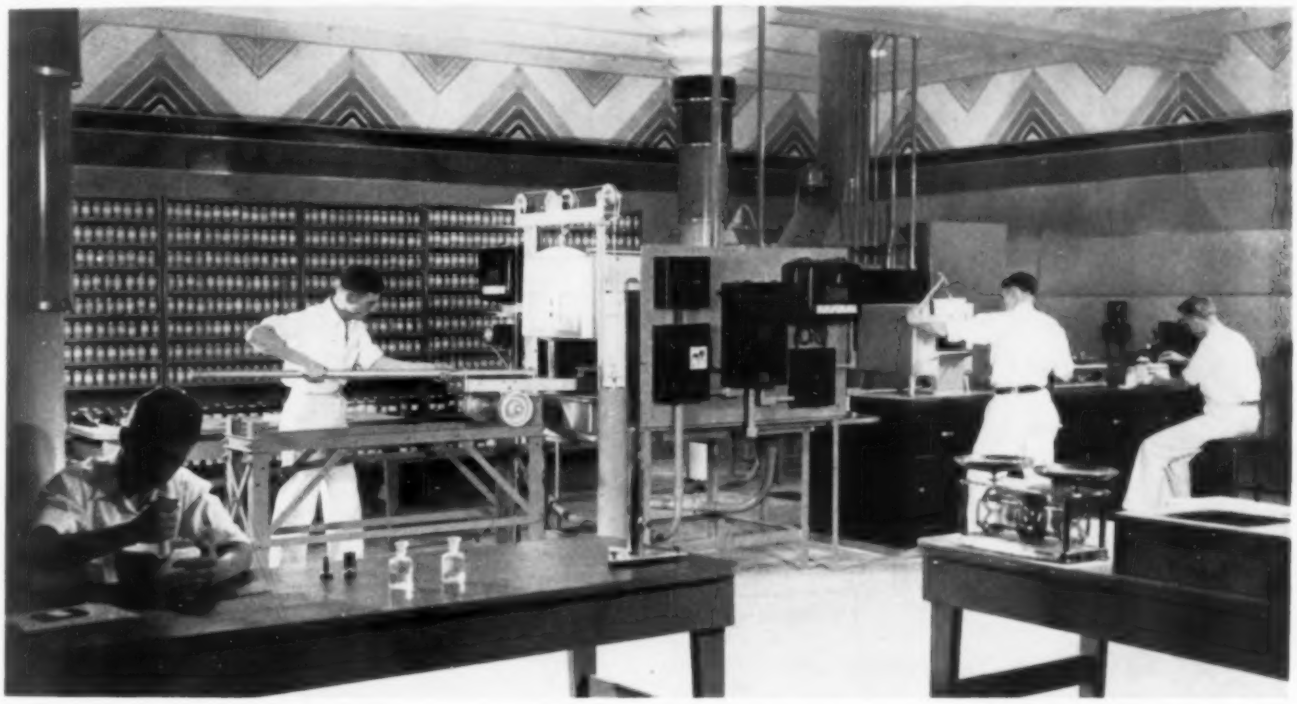
for an improvement whose attainment requires the acquisition of new knowledge, he is really casting his ballot for a research expenditure. Whenever a salesman transmits such a demand to his technical or operating associates, together with his own comments, he also is helping to guide research.

Since all of us share the responsibility, we may well inquire into the conditions favorable to profit from research. First, we should perhaps define more fully what we mean by profit. There are various parties to be considered, and to be regarded as commercially successful, research should yield a value greater than its cost to the party which bears that cost (whether such party be the public or a private business) and should be profitable to the individuals doing the work in the sense that they should get a greater combination of enjoyment and compensation than they could receive from some other type of work.

In considering a research project, the first problem is to estimate the probable cost, and the possible value of the results. In the latter, we immediately encounter the fact that any single project of this type is quite speculative in character. The results cannot be accurately predicted, and this is inherently true, because if they could be predicted, no research would be involved. We can, however, assume that the project will be technically successful, then estimate its possible commercial value, and thus arrive at a maximum possible value of the undertaking. Since the odds are usually against a completely satisfactory technical outcome, the possible value should usually be several times the estimated cost.

Researches on processes are usually conducted with the object of effecting savings over existing processes, and then the possible value can be estimated by operating men familiar with existing processes. To illustrate by a simple example, a concern doing a large amount of sulphuric acid pickling was approached on a proposition that steel could be cleaned more cheaply by another method. The saving claimed for the new method was found to be greater than the total existing cost of cleaning by pickling. The men who made the proposal had wasted their time because they did not know pickling costs for the particular type of work involved.

The possible value of research on new prod-

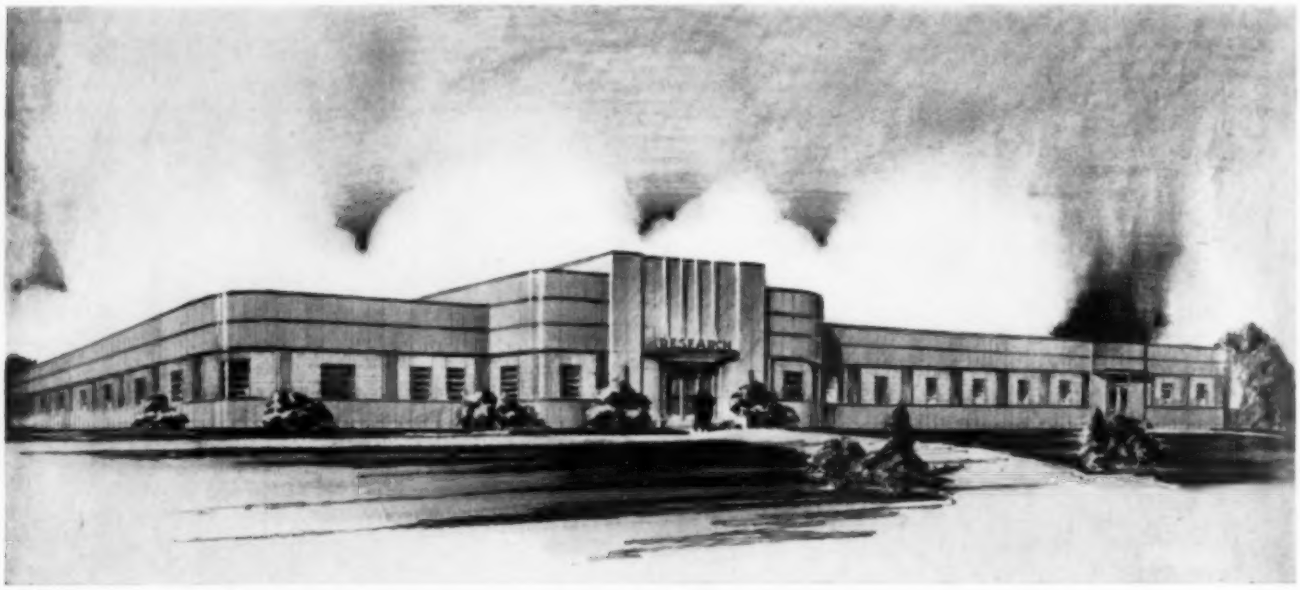


Walls, Ceiling and Columns in Main Research Laboratory of Chicago Vitreous Enamel Product Co. Are Finished in Acid-Resisting Porcelain Enamel in Harmonious Colors. Generous use of stainless steel strip at joints enhances the effect. Consultant on architecture: R. Harold Zook. Consultant on color: Louis W. Weinzelbaum. Hedrich-Blessing photo

ucts depends greatly on markets. Much money has been wasted on the development of products whose greatest possible sale could not justify the development cost. This error is now better appreciated than formerly, and it is more common to find market analyses made before the expenditure of considerable sums on the development of new products. Market analysis is in itself a type of research, however, and one which requires just as great skill as physical research. L. S. Hamaker has developed this phase of the problem in an interesting article in METAL PROGRESS just a year ago.

While any single research project is a highly speculative investment, it does not necessarily follow that a program involving *several* projects is equally speculative. In fact, there is reason to believe that a sound research program, ably conceived and executed, may be one of the most certain as well as profitable investments. One line of evidence for this proposition is found in the fact that certain large and very successful corporations have persistently carried on their research programs, with little or no retrenchment, throughout the depression. As a single instance, note the statement by Mr. Litchfield, inserted by the Editor on page 261.

We are accustomed to thinking of scientific and industrial research as an activity which has been carried on only in recent years with respect to the entire period of human history. We are also conscious of the great and accelerating rate of technical progress in the past 150 years. We



"It Is Fitting That Research Men, Who Will Lead the Way to Progress and a Higher Living Standard, Should Themselves Be Housed in a Building Applying the Latest Results of Their Research," says Charles R. Hook, President of American Rolling Mill Co., in Releasing This Architect's Drawing of the $260,000 Research Laboratory That Is Now Under Construction at Middletown, Ohio. The Austin Co., Architects and Builders

forget meanwhile that our ancestors, even back to the ancient Egyptians, produced artisans whose handicraft compares favorably with the best we can produce today.

One of the achievements and still current problems of research is the conversion of the industrial arts into exact sciences. It is interesting and important to note that man has usually learned *how* to make things work before he has learned *why* they work. Steel was hardened for many centuries before the thermal critical points were discovered. Until an art is reduced to a science, performance is apt to be somewhat erratic and the training of new artisans a very slow procedure. Processes are wasteful because minimum requirements are not known. Witness, for example, the importation of water from Sheffield, England, into New York for the quenching of cutlery.

Quality of product, under these conditions, is apt to lack uniformity. While it is doubtful whether modern scientific methods can produce a sword blade as fine as the best that were made in medieval times, the medieval methods were slow and costly, and undoubtedly the per-

centage of poor blades was quite high. This leads us to a significant conclusion, namely, that in some cases at least, the very finest quality of product can be attained by retaining artistic craftsmanship followed by scientific inspection. Sometimes artistic craftsmanship can be aided by scientific measures and controls. It is to be noted, however, with respect to the human element, that men skilled in the application of scientific controls and constitutionally fitted for this type of work are rarely the same kind of men who make the finest craftsmen. The scientist and engineer depend largely on reason, while the artisan depends more on keen observation, in which every one of the physical senses is employed. His observation is often aided by something which we would like to call an uncanny intuition. Perhaps this intuition is really more of a subconscious association of his observations.

Intuition, Observation, Interpretation

The principles which we are here considering can also be illustrated with reference to the fine arts. A player-piano can reproduce music fairly accurately as it is written, but the result does not sound much like the rendition of a fine musician.

Let us now return to the problem of conducting research for profit. Assume that a research program is proper for a given industrial concern — that engineering and market studies have indicated a promising return on various projects. What type of men should be selected to carry out the program?

An interesting paradox here presents itself. Most industrial research organizations are made up largely of college graduates, many with advanced degrees — or at least these are the men we hear about. The paradox lies in the fact that most of the world's greatest contributions to technology have come from men who never went to college — men like Franklin, Edison, and Ford. Creative ability seems to lie in that combination of keen senses, close observation and "intuition" which makes the fine craftsman or artist.

Have our great industries then been wrong in employing men of advanced technical training for research? Not necessarily. In the first place, college training need not submerge the native traits of the type which we may refer to briefly as "artistic." It seems, however, that this type of man is less apt to go to college (or to complete his course if he does go there) than the man who learns more easily from books. A college degree is not incompatible with research ability, but it is certainly no guarantee of such ability. From the statistical standpoint, it might be argued for the college man that the greater creative production of non-college men is quite natural, because there are many more of them, and the ratio has been even greater in the past.

Another point is that modern technology has become so complex in some directions that advanced scientific and mathematical training might be considered essential for even an approach to certain problems. This assumption is questionable.

A factor of considerable importance is the wider range of knowledge of the college trained man, and particularly his education in methods of searching literature and other sources for existing knowledge. Men without such knowledge and training often waste more effort in doing something which has been done before.

Henry Ford has proved himself one of the greatest industrial research directors of all times. To him is attributed a remark that he does not like experts — because they know too damn many things that can't be done! This applies not only to college graduates but also to artisans who are expert in the particular field in which new work is to be done; it is, however, one of the failings of many men of advanced scientific training — they fail to realize that discovery and invention lie in phenomena which are not according to Hoyle.

The Field for College Training

The college trained man, even without creative ability, can be of great help in research work. He can criticize projects, calculate costs, help the creative man of less training by means of his wider background of knowledge, analyze the results of creative work, simplify procedure, and bring processes under control. Successful research is favored both by creative ability and by advanced technical training; these characteristics may not often be found to the highest degree in the same individual; if not so found, they should be made available by drawing upon individuals of both types.

The time factor is of great importance in research. The executives of one of our great industrial corporations which has made research very profitable have concluded that it requires about five years to build up an efficient research

organization. During this period the research men acquire as a background a sense of perspective and efficient research methods. C. F. Burgess, of the Burgess Laboratories, has stated (if I recall correctly) that in his experience about seven years had been the average period from the beginning of a project to the earning of profits. Naturally many projects show a profit in less time, while some take longer.

Thus the building of an efficient research organization and the average time for profitable development of a project are both matters requiring some years. It is, therefore, obvious that the prospects of making money from research are most favorable when the continuation of the research program can be assured for some time — preferably at least ten years. A corollary of this proposition is that the cost of the work should bear a proper relationship to the income or funds available for its support.

Since research unavoidably moves with a slowness which is often disappointing, it is important to use all reasonable means of speeding the work. Some phases of the work, particularly the mental processes, cannot be greatly accelerated. Ten men can think about more different things than one man, but they cannot think ten times as fast. Furthermore, it takes just so long to hatch an egg, and putting several hens on it will not hasten matters. A one-year corrosion test cannot be run in one month.

Time Saving Methods

There *are* ways of saving time, however. Research work is not moving as rapidly as it can when the men are frequently interrupted to attend to other matters, such as production problems. It is largely for this reason that a separate research organization is established, independent of the technical organization responsible for production control. This separation has some disadvantages, however. Research men thus separated are usually not in a good position for semi-commercial research using plant facilities. Furthermore, when a project has reached such a stage that it should be introduced into regular plant operations, it is turned over to men who are relatively unfamiliar with it, and perhaps unsympathetic. Whether the research organization should or should not be separate, however, should be decided in each case; both profitable and unprofitable research has been done by both methods.

Time can also be gained in other ways, especially by avoiding delays in shop work and in testing. In a certain laboratory having as one of its functions the development of aluminum alloys for castings, it was at one time the practice to cut accurate threads on all tensile test bars. This was done at the insistence of a highly trained testing engineer. Because of congestion of work in the machine shop, the average time between the pouring of an experimental heat and the pulling of the bars was four days — four days before the next experiment could be guided by the last! This machining was entirely unnecessary except for very brittle alloys; when the practice was discontinued except in such cases, the result was that tensile test results were sometimes available within half an hour after casting the bars. It was then possible to make and test as many as four melts in one day, each guided by the results of the last, instead of one melt in four days — a ratio of 16 to 1 in speed.

The testing engineer had in this case impeded progress by being too meticulous, and had also wasted much money. This type of mistake is frequently made. Many earnest investigators feel that testing for research purposes is more exacting than testing for production control. The reverse is often the case. In the early stages of a project the object is likely to be a rapid and economical survey of broad fields to find restricted regions worthy of more intensive cultivation. In this exploratory work we are looking for marked differences in properties and even qualitative tests may be adequate. In later stages of the work more exact determinations, sometimes of the highest possible precision, may be required.

Research Can Be Profitable

Is research work profitable to the individual doing the work? Perhaps we can refer again to the imperfect analogy of the quest for gold. It is said that total expenditures in this quest have greatly exceeded the value of the gold recovered. Perhaps the total expenditures of all those who have sought to discover and invent have also exceeded the rewards of the small percentage who have been successful. Failure among individuals has been so common that inventors are commonly expected to be poor.

But much of all this effort and expense has been in rather hopeless causes. Men are still working on perpetual motion machines, redis-

covering the carburizing of steel, and the "lost art" of hardening copper. The technically trained man has a great advantage in this respect over the man of less training; he is not so apt to waste time duplicating work which has already been done, or attempting something which clearly is against one of the few relatively fixed laws of nature.

Even though the inventor is successful in his purpose, and his invention worth more than its cost, he may fail to profit because of lack of business ability, whether he works alone or is employed by others. In short, research as a vocation does not guarantee either profit or loss to the individual, any more than law, selling, or banking. It has been and is profitable to those who are suited for it by native abilities, temperament and training — and unprofitable to others.

How Research in Rubber Contributes to Modern Ways of Living

By P. W. Litchfield, President, Goodyear Tire & Rubber Co., Akron, Ohio

THE RUBBER INDUSTRY, from the very beginning, has been based on scientific research. The uses of rubber were strictly limited — actually there was no rubber industry — until Charles Goodyear discovered the secret of vulcanization in 1839 after much patient experimentation.

Other discoveries, making new landmarks in the development of the art of rubber manufacture, and increasing its field of useful service were these: Development of a process to "reclaim" used rubber (1899); discovery of accelerators to quicken the vulcanization process (1906); use of carbon black and other pigments to increase the durability of rubber compounds (1916); development of a commercial process to make synthetic rubber (1931).

These significant advances, together with many others, have been combined to make rubber an increasingly valuable contributor to modern ways of living. Goodyear established its own development department in 1908, when organized research was still relatively new to American industry. To this department was assigned the three-fold task of (1) designing new products, (2) testing all products to assure high quality and enduring performance, and (3) checking the work of production at every step.

Our record of building and selling more than 250,000,000 pneumatic automobile tires may be credited in large part to the fact that during the past ten years the company has spent nearly $17,000,000 on research and product development alone. Today 409 persons at Goodyear devote their full time to devising ways and means of making better products and finding wider uses for them.

One hundred years ago rubber was used in only limited quantities, chiefly for waterproof clothing and footwear. Now it is manufactured into tens of thousands of different articles, of which automobile tires are by far the most important. Today's unprecedented consumption of rubber may be attributed chiefly to (1) the demand for larger passenger car tires; (2) the increasing use of pneumatic rubber tires on trucks and farm implements; and (3) the continual development of new industrial uses for rubber. (In the modern motor car, for example, fully as large a tonnage of rubber products is needed for such things as engine mountings, runningboards, and steering wheels, as for tires and tubes.)

Since the manufacture of automobile tires is the most important branch of the rubber industry, the aid of science has of course been enlisted here to help produce safer, stronger, longer-lasting tires. It is a matter of satisfaction to record that Goodyear has played a leading part in pioneering many of the outstanding advances in tire design and construction. Research and development work were never more important to the rubber industry than at the present time. Today's passenger cars and trucks, traveling at high speeds, carrying heavy loads, stopping and starting quickly, put an enormous burden on tires.

Confronted with such engineering problems, Goodyear's research experts are engaged today on the tires of the future.

PHYSICISTS MEET THE METALLURGISTS

By Robert F. Mehl ⊕
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As a part of a general program designed to bring together various groups of scientists and engineers to discuss the status of scientific knowledge in the various engineering fields, the American Institute of Physics in collaboration with the Massachusetts Institute of Technology sponsored a three-day symposium on metals, held at the latter Institute in Cambridge, Mass., late in January. In the mind of this reporter, the meeting was a grand success.

It is really quite obvious even to a casual commentator that the rapid growth of the sciences and the various branches of engineering will require frequent discussion of problems common to both fields, for no longer may one man be competent to hold all of the sciences within his grasp, nor can a practicing engineer be expected to be fully conversant with the advances in the scientific fields that pertain to his immediate interests. The metallurgist occupies a position of particular difficulty in this respect: Apart from his specialty in metallurgical engineering he should be thoroughly grounded in physical chemistry if he is to understand the reactions that occur in the refining of metals, he should be well acquainted with electrochemistry if he is to understand corrosion, he must be well trained in physics and mechanics if he is to be intelligent in his handling of metal-working problems and if he is to be capable of devising and interpreting physical tests, and so on, nearly *ad infinitum*. The growing number of symposia being held by American societies is a proof of the need for a wider knowledge to counteract growing specialization.

With this in mind, eighteen speakers presented papers at Cambridge on the various aspects of metallurgy upon which physicists might be of help and on various chapters of physics which might be basic to metallurgical phenomena, hoping that a statement of unsolved problems would inevitably lead to some efforts toward their solution by the common interest initiated in this way. The interest of the several hundred in the audience, many of whom had been sent by industrial companies from a considerable distance, must have been gratifying to the sponsors of the meeting. Summaries of many of the papers may be secured from Prof. John Wulff at Massachusetts Institute of Technology, who was in charge of the arrangements. Doubtless a formal publication will also be available eventually.

Starting with the most basic of all metal problems, namely, that of the electronic structure of the metal atom, J. C. Slater, professor of physics, M.I.T., described in simple and most lucid terms the physicist's present ideas of the nature of the metallic state, following a treatment somewhat similar to that given in a recent

number of *Review of Modern Physics* and to those in recent books by Hume-Rothery and by Mott and Jones. Let it not be thought that this is a theoretical and therefore (the "therefore" is all too prevelant among engineers) an impractical matter! For with such science the factors which determine the constitutions of alloys — what intermediate phases should be (and *are*) present, what the solidus and liquidus temperatures should be, what the degrees of solid solubility should be — are now finally, after these many years of alloy study, beginning to be understood, and sound predictions for uninvestigated alloy systems made.

Following, perhaps for purposes of relief, the present writer discussed the metallurgical problem of diffusion in alloys, pointing out the many instances where diffusion is the major process operating in metallurgical processes. In discussing the factors which determine the rates of diffusions in alloys and thus also determine the rates of processes such as carburizing, age hardening and a host of others, the basic problems were outlined upon which the physicist must lend his aid if progress is to be had. Much of this same ground has been covered in addresses before ⊕ chapters.

F. Bitter, associate professor of metallurgy at M.I.T., described the several problems in the physics of metals upon which he is engaged. Of particular interest is that of magnetic methods involving careful physical analysis to determine the extent and type of preferred orientations in cold-worked metals and also to determine the state of internal strain. He described also his recent studies on the factors that determine the occurrence of ferromagnetism in alloys. These studies are probably as good as any to exemplify problems where a knowledge of both physics and metallurgy are required.

In his usual entertaining style, V. N. Krivobok of Carnegie Institute of Technology and Allegheny Steel Co., spoke on the mechanical behavior of stainless steels, following in a large part his Campbell Lecture and his recent paper to the ⊕ on the effect of variations in the composition of 18-8 on the properties following cold work. (This was summarized in METAL PROGRESS in Nov. 1934 and Oct. 1936.) He stressed particularly the remarkable variations in properties which can be obtained in this alloy with variations in composition, with mechanical treatment and with aging treatment. If the physicists present lent but little help in supplying the missing explanations in this and other instances, let it be credited to the inherent difficulties in the science of metals, rather than to any lack in the physicists!

R. M. Burns of the Bell Telephone Laboratories presented a carefully developed treatment of the corrosion of metals and alloys, discussing the manifold complications which prevent any simple theoretical treatment but none-the-less clarifying to many of those present the nature of the myriad problems involved. Many of his thoughts have already been put in print in a series of articles in *Bell System Technical Journal*. John Wulff of M.I.T. then spoke very entertainingly on pit corrosion, illustrating his address with exhibits. Evidently the magnetic method is one of the most sensitive in disclosing the early stages of the decomposition of austenite in stainless steel, and evidently also pit corrosion is and will probably remain a major problem, practically and scientifically. One of its practical consequences was discussed editorially in METAL PROGRESS, Feb. 1935.

Lead-In Wires

Some measure of leavening to a rather serious meeting was afforded by the address and the discussion thereto by A. W. Hull of the research laboratories, General Electric Co., who described recent developments in alloys that reproduce the expansion characteristics of glass and thus perform admirably when sealed in glass (see METAL PROGRESS, Dec. 1935). For this purpose the sum of the variations in the amounts of the many metals present in the alloy must not exceed 0.15%. But any suspicion that difficulties in meeting such a severe specification lay in the inadequacies of the metallurgist was promptly dissipated by several of these gentlemen who remarked that the problem is one of the purchasing agent and not the metallurgist!

Speaking on the subject of flow phenomena in heavily stressed metals, P. W. Bridgman, professor of physics at Harvard University, described his recent experiments in which thin metallic sections are given an extreme amount of cold work in torsion, and by the necessary applied torques disclose the occurrence of hitherto unknown transformations and much new information on the plasticity of metals. A. V. deForest, associate professor of mechanical engineering at M.I.T., exhibited a steel spring wound in such a way as to be in compression even though tightly packed and described the ingenious way in which this had been done. His

address was on "The Elastic Properties of Ferrous Metals at Room Temperature," and he described also his recent studies on creep, particularly as applied to springs for seismographs where the requirements are severe. A. Nadai, physicist of the Westinghouse Research Laboratories in Pittsburgh gave a detailed and mathematical account of the plasticity of metals as revealed in creep.

C. L. W. Trinks, professor of mechanical engineering at Carnegie Institute of Technology, described the mechanics of rolling, revealing to the audience the principles which operate in the simple and the complex types of rolling, making his address graphic with some excellent slides.

The director of applied physics at Massachusetts Institute of Technology, G. R. Harrison, gave a very valuable summary of the accomplishments and limitations of spectrographic analysis of ferrous materials, stating with great clarity the types of instruments that should be used and the degrees of accuracy which can be obtained. The progress in this branch of science is gratifying, at least to this spectator. In a somewhat similar vein J. T. Norton of the same faculty discussed the use and limitations of X-ray diffraction.

C. J. Davisson of the Bell Telephone Laboratories chose a subject of considerable interest to the modern scientist of metals: "What Electrons (Electron Diffraction) Can Tell Us About Metals." Especially in studies on the structure of thin films, including oxidation and corrosion films, and in the structure of severely worked films, electron diffraction is contributing entirely new information. As the reader will know, the English group of scientists working recently in this field believes that electron diffraction has proved the existence of amorphous metal in polish layers. Is it not a strange circumstance that the modern high-brow (to use Dr. Gillett's oft-repeated but atrocious term) has perhaps *proved* what the high-brow of ten years ago *disproved* and only the low-brow accepted? Perhaps being high-brow is a matter of age! But the end is not yet in this question, for upon cross-examination, Dr. Davisson stated that the interpretation of electron diffraction photograms of polished metals is still in the controversial stage and implied that the metallurgist might as well keep the opinion he has for the moment.

In the last formal session the metallurgist alone held forth, with our own past-president Jeffries giving an interesting account of the newly developed tool materials, with A. B. Kinzel of the Union Carbide and Carbon Research Laboratories proposing that all (or most) processes of embrittlement in steel might have their origins in peripheral ("hoop") stresses around "non-ferritic particles," with S. L. Hoyt of the A. O. Smith Co. discussing powder metallurgy in a delightful way, and with E. C. Bain of the United States Steel Corp. and president ⊕, relating his own work on the rationalization of the austenite-pearlite, austenite-bainite, and the austenite-martensite transformations. I have not given any details of these addresses only because their authors and their subjects are so familiar to the metallurgical fraternity which reads Metal Progress; they served a valuable purpose in disclosing to the physicists the complexities in metallurgical phenomena. If they served also to dissipate the unconsidered opinion I have found in some quarters that the metallurgical scientist is really not much of a scientist, they served admirably well. Indeed, in the opinion of your reporter, the metallurgist at this meeting acquitted himself with distinction: his science is complicated and inherently difficult, but he knows a tremendous lot about it.

Following the meetings, the extensive research laboratories of Massachusetts Institute of Technology were held open for inspection; several groups journeyed to the Watertown Arsenal for a similar purpose. At a very pleasant dinner at the Copley-Plaza, President Compton of M.I.T. spoke on the objectives of these symposia, and Albert Sauveur spoke on the early metallurgists, "conferring" 21 honorary degrees and entertaining his audience in that delightful way which has endeared him to all of us.

Such symposia as this should be — and are to be — repeated. Need there be any better argument in justification of research in the science of metals than the untold dollars which have accrued to the metallurgical industries from the greatly improved modes of thinking by metallurgists that resulted from the scientific writings of Jeffries and Archer on slip resistance and on recrystallization and grain growth a little over a decade ago? Or the tremendous engineering development of age hardening alloys which followed Merica's statement of the underlying principles? Let the engineer and the industrial executive lend his ear — and his pocketbook — to the scientist in metals whether in industry or in the university. The thought of that scientist and the experiments of that scientist are leading to the new metallurgy!

ADVANTAGES OF ALLOY STEELS

By A. L. Boegehold
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An article in the February issue of Metal Progress discussed the inherent limitations of heat treated carbon steels, even when of the best commercial quality, as far as their applications to important automotive parts are concerned. This sequel will now attempt to indicate how some of these limitations are removed by alloying. A third article, next month, will discuss the type of investigations and information necessary prior to an intelligent selection of a new alloy steel.

Steering Knuckle — One important point brought out in the previous article is that plain carbon steel, when heat treated to high strength and hardness, is unreliable when the part is irregular in shape and cross-section. The steering knuckle is an odd-shaped part having surface irregularities which cause stress concentration. It is a very important part and if broken in service would endanger life. Material and heat treatment must therefore be such that there exists a minimum possibility of failure. Although the section size is somewhat lighter than the crankshaft, for which carbon steel is satisfactory, the amount or depth of hardening which could be obtained in plain carbon steel even with a water quench would not be sufficient to insure the most reliable result. Danger of cracking also would always attend water quenching — and by that is meant internal micro-cracks or even submicroscopic cracks rather than evident surface cracks. Steering knuckles are made from the medium manganese steels S.A.E. T1340 and T1330, chromium-molybdenum 4130, nickel-chromium 3140 and carbon-molybdenum steels. The hardness varies between 241 and 302 Brinell on most knuckles but on others is up to 340. There is considerable machining to be done after it is heat treated (which is another reason for using alloy steel for this part, since steels like 3140 and 4130 may be readily machined up to a hardness of 340 Brinell).

The variety of steels in use for steering knuckles recalls the statement made earlier in the discussion that there are too many steels. In the class of steel used for steering knuckles we have the S.A.E. steels mentioned above and in addition straight chromium steels, chromium-vanadium steels and 3½% nickel steels, all in carbon contents at or about 0.40%. Some of these are used much less than they were some time ago, for there is not enough difference between them to justify their existence. The tendency is to gravitate to the use of the ones in this group that are at the lower end of the price scale. Any one of the steels mentioned would, when properly made and heat treated, be perfectly satisfactory for a steering knuckle. The same remarks would be appropriate in connection with the 0.30% carbon grade of the same six alloys.

Gear Requirements — Automotive gearing comprises a class of parts wherein the peculiari-

At Left Are the Helical Gears in a Syncro-Mesh Transmission; at Right Are Pinion, Ring Gear and Differential Assembly. Photographed in the Cadillac plant a couple of years ago by Anton Bruehl, the details may be slightly altered on 1937 cars, but the photography could hardly be improved upon

ties of alloy steels are carefully used. This subject has had as much intensive study as any problem in production engineering, and I naturally have space here for only a brief statement of some of the more important metallurgical considerations.

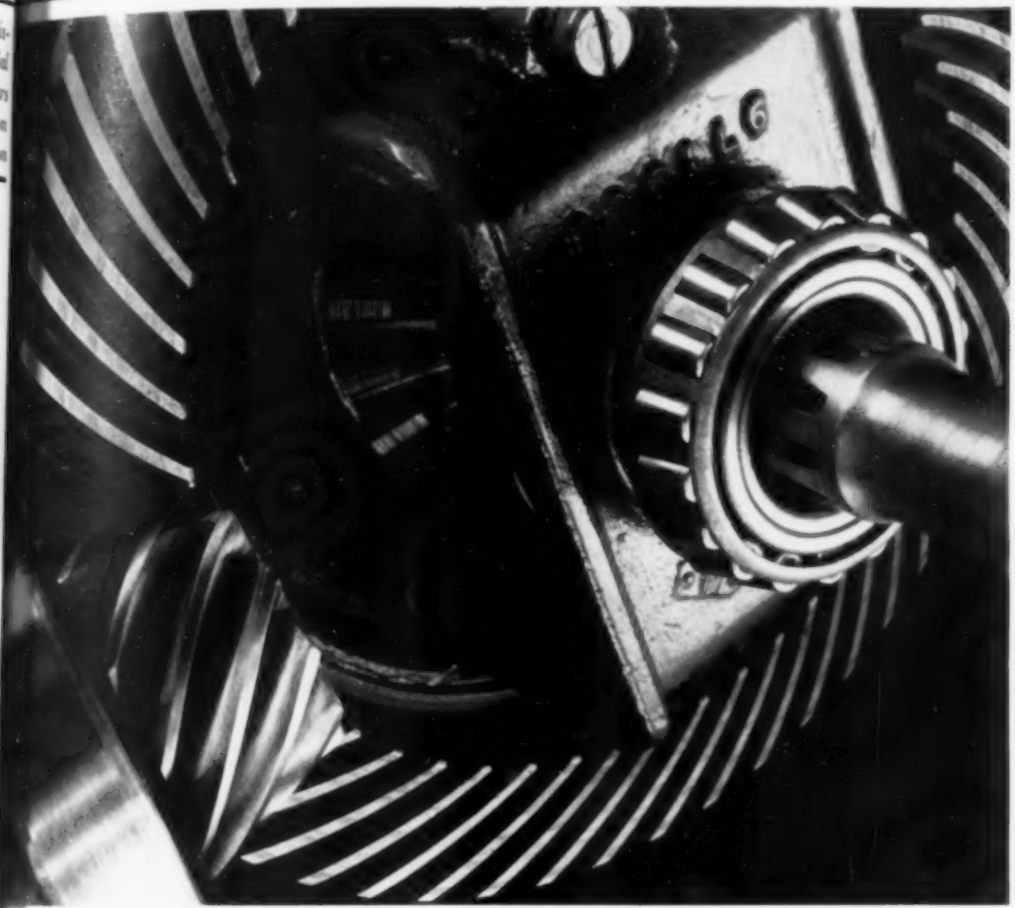
In attempting to get durability in a gear of almost any type, the metallurgist is at the mercy of the engineering and manufacturing departments. Improperly shaped teeth with inadequate fillets at the roots of the teeth will nullify his best efforts to supply a durable gear of long life. In the same way the manufacturing department, by using improperly shaped tools, causing sharp tool marks where the engineer intended to have fillets, can nullify all the good efforts of the engineering design.

The wear resistance of file hard, carburized, plain carbon steel is just as good as that of the alloy steels, so the necessity for using alloy steel for these parts in some cars is a matter of supplying strength to resist higher stresses. These stresses may in some instances arise from excessive loads and good design, or in other instances from low loads and bad design (stress concentration). Side gears and differential pinions are of such shape and size that distortion can be controlled within satisfactory limits, even with a water quench which is used to get the desired tooth hardness for wear resistance.

Distortion occurring during hardening is an occurrence which has especially to be taken into consideration in all parts that are used without finishing operations after heat treatment. Parts that are finish machined before heat treating are those which, because of the high stresses imposed or because of a requirement for wear resistance, must have a hardness too high for machining. Some of these parts of high hardness may be sized after hardening by grinding, but there are some parts such as gears that do not lend themselves readily to grinding because of their shape, or because grinding removes a layer of metal of high surface hardness, expressly created by heat treatment. Distortion is particularly bad on these highly stressed parts, not only from the standpoint of imperfect functioning, which causes undesirable noise, but it usually results in considerably increased stresses in the part due to concentrating the loads on smaller areas. We find, therefore, that in all highly stressed gears we must use steels that do not require drastic quenching to harden, even in fairly heavy sections.

Transmission Gears are a notable example of the type of gear just discussed. It is quite general practice to make them of oil-hardening steels with either enough carbon to obtain strength without carburizing or with low carbon strengthened by carburizing. High surface hardness for wear resistance is required in all instances, and this is obtained either by a dip in cyanide, or by heat treating in a controlled atmosphere which produces an intensely hard layer at the surface the equivalent or slightly better than cyanide.

Quite a number of different types of alloy steel are being used for transmission gears including nickel-molybdenum S.A.E. 4620, 4615, 4640, and 4815, nickel-chromium 3145, chro-



mium-vanadium 6150, and chromium steels 5135 and 5145. If there were only one type of alloy steel with 0.40% carbon, instead of four or five, each with a range of carbons, it is quite probable that all car makers could use it and get along just as well as they do at present. (For those who are using the highest cost steels, savings are possible by slight engineering changes, should the lower cost steels be unsuccessful without such changes.) Gears made from the higher carbon type are heat treated to Rockwell C-52 to 55, and those that are carburized are hardened to C-58 to 60. At hardness in this range, particularly when the hardness exists *throughout* the part, it is extremely important to have as much ductility as possible to assist in stress redistribution at points of stress concentration. This, as pointed out in the article last month, is an added reason why alloy steel is desirable.

Those who use the carburizing grades of these steels do so because the loads are definitely higher than the 0.40% carbon varieties will endure. Under conditions of repeated loading and stress concentration, such as exist at the base of gear teeth, the carburized material is at least 50% stronger than the uncarburized alloy steel.

Ring Gears — The question of distortion is even more serious in rear axle ring gears and pinions, not alone because of stress concentration but also because of noise. So important is this that it was the principal factor responsible for the selection of S.A.E. 4615 nickel - molybdenum steel by a number of companies. It has since been demonstrated that the method of manufacturing the steel had as much to do with this behavior as the composition. Low distortion is obtained only when this is quenched direct from the carburizing box; a reheat and quench will cause much greater change in dimension and shape.

In answer to those who suppose that plain carbon steels can be used for all car parts, let us picture the result if carburized 1020 steel were used for ring gears and pinions. In the first place, the gear would have to be quenched in water or brine to get the teeth hard enough to resist wear. The resulting distortion would be excessive and would cause noise and localization of load, leading to early failure. Since recent designs of rear axle gears and mountings have resulted in improved tooth contacts during operation, it has been possible to reduce the size of these gears. Some of the reduction has been accounted for by taking advantage of the full strength of the alloy steel. If made in these revised designs it seems probable that a gear of plain carbon steel would experience early failure, even if it could be hardened *without* distortion. Whether the fact that plain carbon steel carburized and fully hardened is weaker than similarly treated alloy steels is due to residual stresses in the plain carbon steel as a result of drastic quenching or whether it is inherently not

so strong, has not been determined — but the net result, practically, is the same.

Rear Axle Shaft — The amount of torque imposed on the rear axle shaft, the amount of bending (which is determined by the weight of the car), the size of the shaft and the location of the bearings, plus the amount of flexibility which the engineer considers permissible or desirable, determines what size the rear axle shaft is to be. This also determines what the stresses will be. The engineers responsible for the design of the various cars on which we have information would appear to have ideas that differ considerably as to the amount of flexibility permissible or desirable because the hardness range is as low as 293 to 321 Brinell for some axle shafts and as high as 400 to 444 Brinell for others. The rest are somewhere between these two extremes. Another explanation for the variation in hardness or strength could start with the assumption that all shafts were to have the same amount of over-all flexibility but that the design of some of them involves greater stress concentration at certain places.

In all probability, a combination of these two explanations for the different hardness in shafts is correct. Most of those in which the hardness is held below about 340 Brinell are machined after heat treating. Some shafts of higher hardness are machined after heat treating and here is where we see one of the reasons for the selection of those steels that have better machinability at these high hardness ranges. They are more expensive and consequently the management must decide which course is to be pursued — *(a)* whether a cheaper steel will be machined before heat treatment (the latter conducted under controlled atmosphere) and with suitable operations to maintain or regain accuracy of shape, or *(b)* whether a more expensive steel will be heat treated first and then accurately machined after heat treatment at somewhat greater cost on account of the higher hardness to be machined. The same question is to be faced in the higher hardness range of 400 to 444 Brinell, but here the decision has apparently been to machine before heat treating. There are some cases, however, where shafts even of this high hardness range are machined after heat treatment. To do this, it is necessary to use a still more expensive steel, namely one like nickel-chromium-molybdenum S.A.E. 4340 which may be machined with reasonable speed at hardnesses even higher than 444 Brinell.

The factors, then, determining the selection of steel for the rear axle shaft are *(a)* stress, *(b)* size and *(c)* machinability. The stress and size determine the flexibility of the shaft. For two different sized cars, the stress might be exactly the same in both shafts. Assuming that the smaller shaft would harden satisfactorily when made of plain carbon steel, then the shaft for the larger car being larger might require a steel with some alloy in it in order to obtain proper hardening. Another way of handling the shaft for the larger car might be to leave it the same size as the smaller car, thus making the stresses higher. This would, of course, result in a shaft of greater flexibility, which might not be tolerable. But if it were, the shaft might then be made of plain carbon steel, heat treated to higher hardness and machined before heat treating. The circumstances against this, however, are that water quenching would be required to harden the plain carbon steel and distortion would then be too difficult to control, and would veto hardening as a final operation.

Faced with these possibilities, the metallurgist will probably, and usually does, select an alloy steel for the high hardness shaft so that his trouble with distortion and machining will be less. A steel that requires water quenching to harden fully will tend to distort more, and is not as well adapted for hard shafts which must be machined before heat treating. It is a fortunate circumstance that steel containing enough alloy for oil quenching is more suitable for heat treating after machining on account of its reduced tendency to distort. If a low alloy steel, such as the 1.75% manganese steel T1330, were used for a shaft which required a high hardness, say around 400 Brinell, and the distortion could be satisfactorily controlled by some type of fixture or die quenching, then we would have to pay especial attention to designing the shaft to have a minimum opportunity for stress concentration at any point. This is because a water quenched steel given a low enough draw to produce a hardness around 400 Brinell would undoubtedly contain some residual quenching stresses which would be localized at points where stress concentration under load would occur, and the result would be a premature failure. An attempt to diagnose the cause of failure by making physical tests on the broken part would probably leave the diagnostician mystified, because such tests would be likely to show strength and ductility equal in every respect to that of a successful material in the same part which had been oil quenched.

The difference is that the latter is comparatively free from residual quenching strains.

For those high hardness shafts which are machined before heat treating, the preferred method of heat treating is in a controlled atmosphere of a kind that will not remove any carbon or form any scale at the surface of the shaft. Any decrease in carbon at the surface will seriously impair the strength of the shaft; formation of scale usually also produces some pitting which causes stress concentration at the surface with consequent low factor of safety.

Controlled atmospheres of the desired type may be prepared by burning natural gas or hydrocarbon fuels with an amount of air calculated to give a composition of combustion products suitable for the steel to be treated and the temperature of treatment. (This in itself is a large problem but, as noted, it has been successfully solved in specific installations.) The combustion products are cooled to about 35° F. to remove excess water vapor formed during combustion, and may have their composition further adjusted by adding measured amounts of organic gases.

The circumstances just discussed are the principal reasons why there are such a variety of steels used for axle shafts and why such a range of hardnesses exists. The steels being used for axle shafts are plain carbon S.A.E. 1040, 1¾% manganese T1330, chromium-molybdenum 4140, nickel-chromium 3140 and carbon-molybdenum steel. In trucks we have nickel-chromium without and with molybdenum (S.A.E. 3240 and 4340) to provide the hardenability required in shafts of heavier sections.

Electrolytic Manganese

Extracts from Annual Report, Jan. 1937, Metallurgical Division, U. S. Bureau of Mines

RECOVERY of manganese from domestic ores presents a peculiar problem in that, although very large tonnages of manganese are available in various localities of this country, little of it is of sufficiently high grade to compete with imported ores. This is so because most of the 250,000 tons of manganese consumed annually goes into the steel industry in the form of ferromanganese which requires a rather high grade ore.

The hydrometallurgy of many of the domestic ores has been developed rather thoroughly; however, there is no satisfactory method for removing the manganese from solution. Electrolysis presented itself as the logical method. Accordingly, the work was concentrated on the electrolysis of solutions containing manganese. Small scale preliminary experiments gradually indicated the proper method of attack.

Manganese has a definite tendency to deposit on the cathode as nodular or tree-like growths. The unevenness causes pockets that are subject to oxidation, and though the deposit may appear to be completely metallic it is possible that it will have a high oxide content. It was found, however, that suitable bright metallic manganese could be obtained on continuous electrolysis of a solution 4 normal in $MnSO_4$ and 2 normal in NH_4Cl and in the presence of a small quantity of SO_2. Fifty grams of metallic manganese that analyzed 99.71% Mn was obtained from such a solution upon continuous electrolysis for 72 hr. at a current density of 48 amperes per sq. ft. and an average current efficiency of 40%. It was found that $(NH_4)_2\,SO_4$ could be substituted for the NH_4Cl in molecular proportions with equal results.

A complete regenerative system for the electrodeposition of manganese was constructed. The electrolyte that contained $MnSO_4$ and $(NH_4)_2\,SO_4$ was circulated from the catholyte to the anolyte to a mixing tank, where $MnCO_3$, representing the raw material, was added, which reacted to neutralize the partly spent anolyte. The solution then passed to a settling tank and completed the cycle by flowing into the catholyte space. A wood separator from a storage battery was used as a diaphragm between the catholyte and the anolyte. Sheet lead was used for anodes and 40 sq. in. of sheet iron for a cathode.

A 48-hr. deposition was made at a current density of 35 amperes per sq. ft. Deposition was interrupted and the cathode removed four times during the electrolysis. The interruptions doubtless added to the impurities in the deposit and were not beneficial to the texture of the manganese.

The deposition resulted in cathodic manganese of 99.85% purity. The deposit was of dense structure, satisfactorily adherent, and had a reasonably smooth surface. There was no evidence of treeing. The over-all current efficiency was 54%, and the current efficiency during the final 9½ hr. was 64%. Power consumption was equivalent to 4.1 kw-hr. per lb. of manganese.

Manganese ore samples were then obtained from various localities. A larger regenerative electrolytic system was designed and constructed, together with a small improvised leaching system. The electrolysis set-up was similar to that of the smaller unit just described. At present satisfactory deposits of 99.8% Mn have been obtained on cathodes about 1 ft. square, from solutions leached from ores such as those of the Las Vegas district.

RENSSELAER HAS A NEW COURSE IN METALLURGY

By Matthew A. Hunter
Head, Dept. of Metallurgical Eng.
Rensselaer Polytechnic Institute
Troy, New York

This article is written in response to an invitation by the Editor and is something of a commentary on the leading editorial (page 253), although mixed in with it is more or less propaganda. While we may object to propaganda on the part of others, it seems that all of us still have a lot of it to do to interest high school boys in a metallurgical career and fill the needs of industry. — *The Editor.*

Four years ago, Rensselaer Polytechnic Institute set up a new curriculum in metallurgical engineering. The compelling reasons were various. In the first place, there had been in previous years many entrance applications from prospective students interested in metallurgy. More compelling, however, was the fact that more than one-quarter of the senior chemical engineers took metallurgical subjects for their theses for graduation and an even larger number entered metallurgical plants after graduation from Rensselaer.

Our experience in this respect was not unique. It was generally known that the metallurgical plants and laboratories were recruiting their staffs from mechanical and chemical engineers. It was very evident that the field of the engineer in metallurgical industry was far from saturated with trained men.

A course following the lines of chemical engineering, with major emphasis on metallurgy, seemed then to fit into the general engineering background of the Institute. This course in Metallurgical Engineering, therefore was established in June, 1933. It was also clear that a new Department of Metallurgical Engineering with better facilities in staff and laboratory could offer stronger courses in metallurgy to the other engineering groups on the campus.

New Laboratory Built

From the standpoint of building and equipment, we are very fortunate. The new Ricketts Laboratory (named in honor of our late president) was occupied in September, 1935. One-third of its available space is devoted to metallurgy. It stands equipped today as the most recent laboratory for undergraduate instruction in metallurgical engineering.

Its facilities include a metallurgical laboratory for the melting, fabricating and heat treating of metals and alloys and a metallographic laboratory for the examination of the metals so produced. These laboratories have adequate equipment for handling a group of fifty students. The laboratories in physical metallurgy are well equipped for testing the physical, electrical and mechanical properties. An X-ray laboratory provides an opportunity in the newer fields of radiography and electron diffraction.

Student Enrollment

Our first experience in student enrollment was rather disappointing to us. It did, however, confirm our suspicion that the high school boy has little or no conception of what metallurgy is and has no idea of the opportunities which it offers as a profession. The class entering in 1933 numbered five men. Since that time we have done a great deal to make the high school boys in this region more metallurgically minded. We approached the councillors in the high schools who direct the activities of the boys, and sent them pertinent literature. Copies of the editorial in the December 1935 issue of Metal Progress entitled "Trained Metallurgists Needed" aroused considerable interest. A descriptive bulletin with pictures of boys at work in the metallurgical laboratory was widely circulated.

The response has been a gratifying one. Our entering freshman class this year numbered 20 young men; total enrollment in all classes is now 50 men. The quality of the entering freshmen is not inferior to the best in the other engineering groups.

Much remains, however, to be done in directing the attention of the high school boy to the opportunities in metallurgy. The American Society for Metals might well consider what part it can play in this development. The local chapters can do much to interest the teachers in their communities. Copies of Metal Progress distributed judiciously in the high school libraries and reading rooms could not help but catalyze the interest of the boys. The well thumbed copies of technical magazines already in these reading rooms are striking evidence of their interest in technical things.

Half of the New Ricketts Laboratory Is Occupied by the Department of Metallurgy. The two upper floors are metallurgical laboratories. The third floor from the top, just above the trees, contains lecture and topic rooms used in common with chemical engineering and aeronautical engineering, whose laboratories occupy the three lower floors (one entirely below grade, since the ground slopes off steeply toward the rear)

Curriculum at Rensselaer

In setting up the curriculum of study for metallurgical engineers we were helped materially by the fact that in Rensselaer Polytechnic Institute we already had in existence the four allied engineering courses, well established in prestige. The Editor of Metal Progress has put

into words in this issue a statement of our original aims:

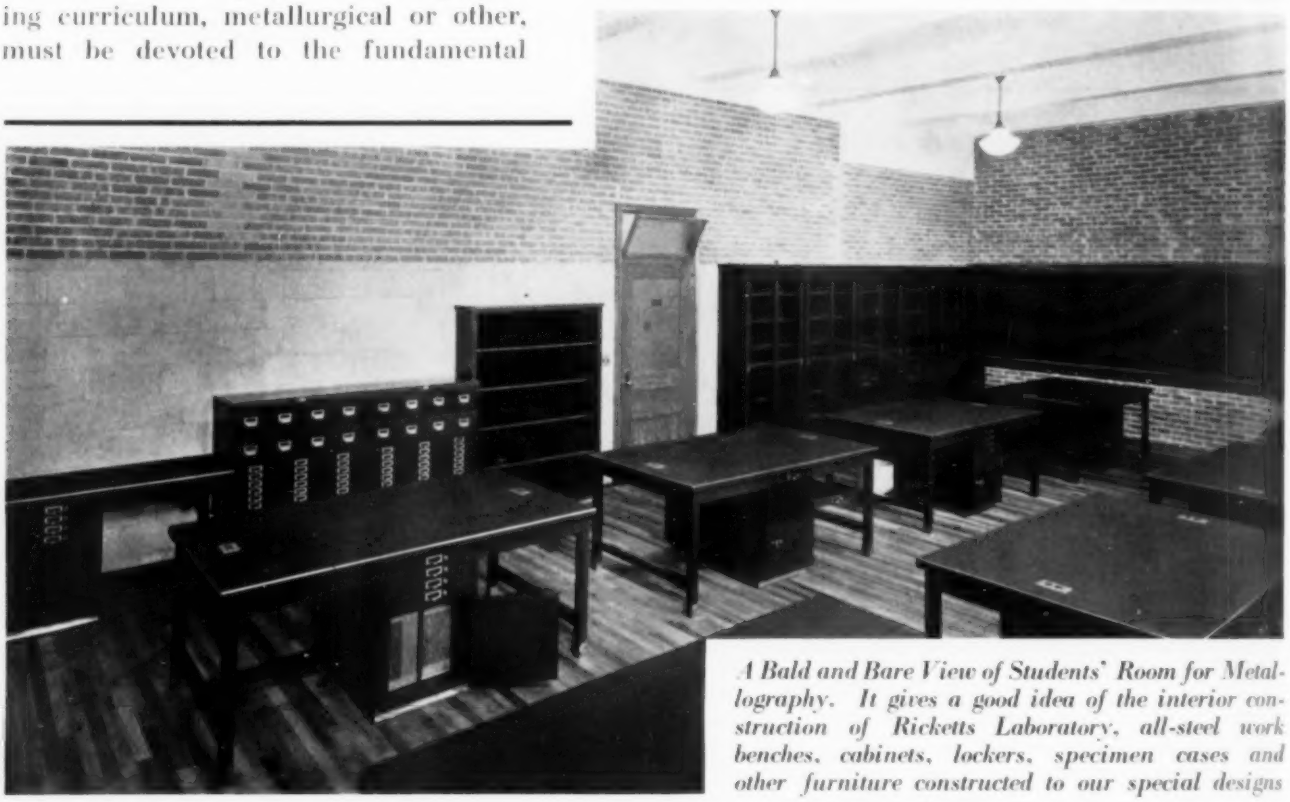
"If a broad education as a metallurgical engineer is desired, how else can it be achieved but by concentrating on the fundamentals of engineering (the sciences) and utilizing an increasing amount of time for free studies in metallurgy?"

The first two years of any engineering curriculum, metallurgical or other, must be devoted to the fundamental sciences of chemistry, physics, mathematics and languages (English and German). We also include at Rensselaer an introduction to economic and industrial history to acquaint the embryonic engineer with present day civilization.

In the two years that are left in which "to utilize an increasing time for free studies in metallurgy," we distribute the time as follows:

Metallurgy
Science and engineering..... 40%
Advanced Sciences
Physical chemistry, thermodynamics .... 18 to 14%
Allied Engineering
Mechanical, chemical, electrical and structural 18%
English
Writing and speaking 9%
Business
Economics, accounting, business administration 9%
Thesis .... 6 to 10%

Metallurgical courses take up 40% of the student's time in his junior and senior year. They are the accepted studies in production metallurgy, physical metallurgy and electrometallurgy and in their associated laboratories, taught, we hope, not as the technique of present practice. In them we are aiming at the "why" rather than the "how" of metallurgical engineering. They are not "free or elective" studies in the sense in which the Editor uses the term in his current editorial. As a rounded introduction to the subject of metallurgy, none of them should be dropped.



A Bald and Bare View of Students' Room for Metallography. It gives a good idea of the interior construction of Ricketts Laboratory, all-steel work benches, cabinets, lockers, specimen cases and other furniture constructed to our special designs

Few would object to further studies of 18% in the advanced sciences related to metallurgy or to the time devoted to the written and spoken word or to the introduction to business.

The Editor's argument for free electives might be directed against the inclusion of 18% devoted to allied engineering. Perhaps this time should be turned over to the electives of which he speaks. In the time we devote to these subjects we never can hope to make the student proficient in any one of these allied branches of engineering. We can, however, acquaint him with the fields in which the metallurgical engineer has made, and is making, his greatest con-

tribution. We can, in addition, broaden his engineering background in a way for which a school such as Rensselaer is peculiarly fitted.

From the viewpoint of the above facts, there seems to me to be but little opportunity in the last two years of a college curriculum for the liberal use of electives. Such an opportunity comes to the engineer in a fifth year of studies in which he proceeds to a master's degree or to the research metallurgist in subsequent years when he is studying for a doctor's degree. During this period, electives are, as they should be, liberal and almost free.

I make a distinction here between the "metallurgical engineer" and the "research scientist in metallurgy" which may need some elaboration. The former adapts our present knowledge to its industrial use; the latter is seeking new knowledge for future adaptation. The door between their respective offices is, however, never closed. Individual aptitude and attitude of mind determine for each individual the course that he should pursue.

Our experience in other fields of engineering has been that perhaps ten per cent of our engineers find advantage in continuing their studies through a fifth year to obtain a master's degree and that a minor fraction of these have the capacity and desire to continue beyond that in independent research in the graduate school in the deeper scientific aspects of their respective fields. I have no reason to believe that the situation will be any different in the graduate school of metallurgy at Rensselaer.

A Wide Variety of Modern Melting and Heat Treating Furnaces, Together With Representative Control Apparatus and a Full Assortment of Measuring and Testing Devices Occupy the Top Floor of Ricketts Laboratory

PROBLEMS IN NON-FERROUS WELDING

By H. W. G. Hignett

Abstract from The Metal Industry (London), Jan. 22, 1937. (Paper for Institute of Welding)

WELDING PROBLEMS may be divided into the following headings: *(a)* Economic, *(b)* engineering, *(c)* metallurgical and *(d)* psychological, realizing, of course, their interrelationship. For instance, two problems recently solved may be classed as both *(a)* and *(c)*. First there is the development of deoxidized copper, without which many important applications of this metal would be impossible; and, secondly, there is the production of nickel with a balanced content of magnesium, sulphur and silicon. Moreover, some of the new alloys, such as Everdur, have welding properties which are too good to be entirely accidental. Apart from these examples, however, there does not seem to have been a concerted effort, on the part of English producers and fabricators, to modify existing materials or evolve new alloys so as to make welding cheaper and easier.

Naturally, a standard evaluation of "weldability" is necessary; Professor Portevin has indicated how this may be achieved (see METAL PROGRESS, November 1933) by the product of two coefficients C and H, where C is a function of the soundness of a joint produced by an accepted welding technique, and H is determined by the degree of uniformity of the useful properties across the joint. One can even now draw attention to some of the more obvious factors entering this problem. The ideal material for welding purposes should have a low thermal and electrical conductivity combined with freedom from hot shortness, and, when molten, should not dissolve large quantities of reducing gases nor form oxides difficult to flux.

Commercially, the attainment of this ideal will be facilitated by the raw materials of high purity now available. For example, aluminum, zinc and copper over 99.9% fine are now readily available. Not only do these very pure metals exhibit to the welder unusual features, such as a fondness for grain growth, but they also provide the opportunity for determining

the exact effects of the constituents usually occurring as impurities, and might also explain the remarkable differences in weldability which sometimes appear between two samples of almost identical composition.

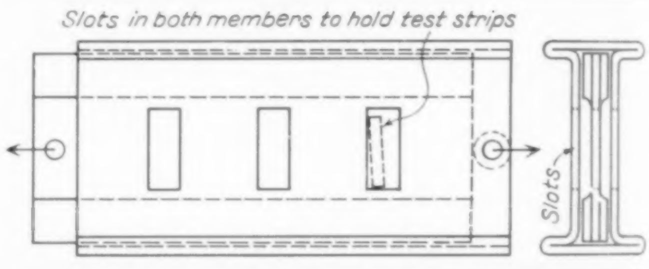
We know that the grain size of an annealed metal or alloy depends, for a given composition, upon the degree of cold work it has received prior to annealing, and the temperature of the anneal. Advantage is taken of this fact in the German *Wulstnaht*, in which the edges of the plates are cold formed before welding. We also know that certain elements, in quite small proportions, have a profound effect upon the inherent grain size of many metals (for instance, titanium in aluminum). It should, therefore, be possible for the welder to be supplied with materials much less subject to grain growth.

Recent work in connection with founding has shown the importance of viscosity and surface tension in determining the "flow-ability" of molten metal, and has emphasized the effects of oxide films and undissolved impurities. Application of the results to welding would explain, for instance, why the underside of a fusion weld in copper differs so markedly from that of a similar weld made with the same flux in aluminum bronze, and might explain many puzzling differences in the mode of transfer of different metals in the welding arc. For example, the order of merit in which a skilled welder places welding generators differs according to the material he has to weld; this does not appear to be a matter of fad or fancy, and is not explained by the usual interpretation of the electrical characteristics.

The gases dissolved by the metal during welding and already present in parent metal or filler rod, also play a part in determining the properties of the finished weld. The importance of this point is not known. It is rarely possible to say with certainty that the gas present before welding has caused the unsoundness of a given weld, but one often suspects it to be a probable factor. It is an obvious requirement that test welds be prepared in all weldable materials on full sized samples, prepared so as to be as free from gas as possible. Until we know the properties of such welds, we do not know how to assess our normal results.

Quite small variations in the freezing range of an alloy have appreciable effects on its behavior during solidification. One effect of increasing the freezing range of weld metal is to provide greater opportunity for the expulsion of dissolved gas. In the case of copper, for example, the addition of silver to the welding rod achieves this object. Again, increased freezing range gives rise to shrinkage cavities in resistance spot or seam welds.

The freezing range of the parent metal — or, rather, its melting range — is sometimes to blame for cases of cracking in materials that are not hot-short in the usual sense of the term. Even aluminum is subject at times to mysterious cracking troubles, and, in one instance, a particular consignment exhibited this fault. Another consignment of almost the same chemical composition and physical properties gave perfect results. Even very carefully conducted tensile tests at elevated temperatures showed both materials to be of excellent quality and to possess no range of hot-shortness. Eventually, the simple apparatus shown in the sketch was constructed to bend, at high temperature, three samples at once and under exactly the same conditions, and showed immediately that there was a distinct difference in the ductility at temperatures very near the melting point.



Fixture of Thin 18-8 Plate for Bending Three Test Strips Simultaneously While Still in the Furnace

With irritating monotony appear the exhortations, "an exactly neutral flame must be used" and "use a slight excess of acetylene." The cheapness of mild steel and its amazing capacity for punishment account for the development in England of blowpipes and regulators with which it is extremely difficult to obey either exhortation consistently. I have in mind a seam made in thin copper plate, with absolutely no adjustment of equipment during the job, yet the beginning of the seam showed the unmistakable evidence of excess acetylene (solution of gas and incomplete expulsion on cooling) and the end of the seam was clearly made with an oxidizing flame! It is obvious that equipment which varies so much with its own temperature is not right for high-quality welding.

IS AVIATION READY FOR STAINLESS?

By E. J. W. Ragsdale
Chief Engineer, Stainless Steel Dept.
Edward G. Budd Mfg. Co.
Philadelphia

It is a strange commentary on the several informative articles in the January issue of Metal Progress that one can build as lightly and at the same time as strongly in wood, the aluminum alloys or in high tensile steel. The physical properties of each balance out against their respective weights. They differ primarily in their bulk and this determines the technique of application. At one time there was a strong sentiment against duralumin because it could not be shaped so as to compete with spruce. Even now that same feeling militates against the use of high tensile steel. Of course, duralumin had to be adapted to structural requirement and this task became simplified as planes and stresses became larger. So, also, must high tensile steel be adapted and, again, so does such adaptation become easier as airplanes assume greater size and are more heavily loaded. Furthermore, with the increased investment and a higher life expectancy in service operations, the utility of a high tensile, corrosion resisting steel becomes more obvious. It seems, therefore, timely to review the subject again.

As said, the weight-strength relations of spruce, duralumin and high tensile steel seem to be about equal. This, of course, refers to the commonly determined physical properties, and these are standard in the laboratory, and are of interest in so far as they may be interpreted into structural strength. Their significance lessens whenever an application makes it impractical to develop these qualities fully in a complete structure. This may come about through structural instability (such as obtained in trying to stand a piece of paper on edge) or through an uncertain means of attachment, such as nailing two boards together. Ingenuity of design can overcome the first, but the matter of attachment may be inherent to the material.

For instance, wooden structures are assembled by mortising, gluing, bolting and the use of metal brackets. None of these inspire confidence in members stressed near their safe limit.

Duralumin is assembled by the time honored method of riveting. Riveting has much to recommend it, especially in dependability, but the rivet hole still remains a source of weakness in the members joined. A joint efficiency of 80% is difficult to better in a single-lap connection of any material. Rivet heads are also an encumbrance, being annoying aerodynamically and in structural clearances as well. Recently a considerable progress has been made in the art of spot welding aluminum alloys. Perhaps the first objection to this will be the large capacity required for the welder and the consequent limitation in its use. This is inherent to the metal, for spot welding is resistance welding and the

aluminum alloys have little electrical resistance, in fact making first class electrical conductors.

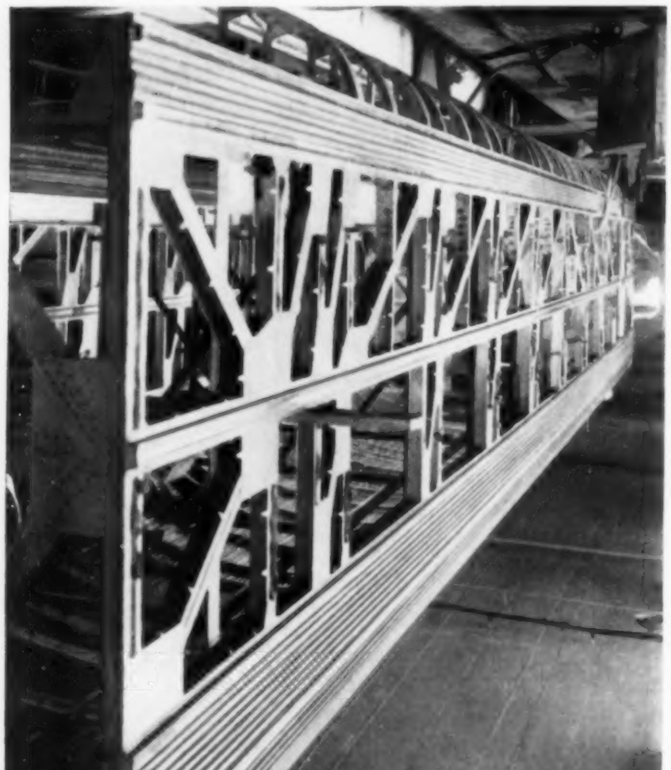
More happy in this respect is 18-8 stainless steel. Its resistance is seven to eight times greater than that of mild steel. This and other properties have helped in the development of the "shotweld" system; which system, in turn, permits a structural assembly of stainless steel with joint efficiencies as high as 98%.

Granted, then, a high efficiency of attachment of 18-8, the problem remains to design structural members that will develop the full strength of the material. Tensile stresses are easy to handle; the difficulty lies in members intended for compression or shear. These beams and struts tend to become complex members, just as do those of aluminum alloys when compared to corresponding wooden members. Fortunately, however, the "shotweld" system permits a ready, effective and cheap fabrication method in stainless steel, so that complexity need not be a matter of any very grave concern.

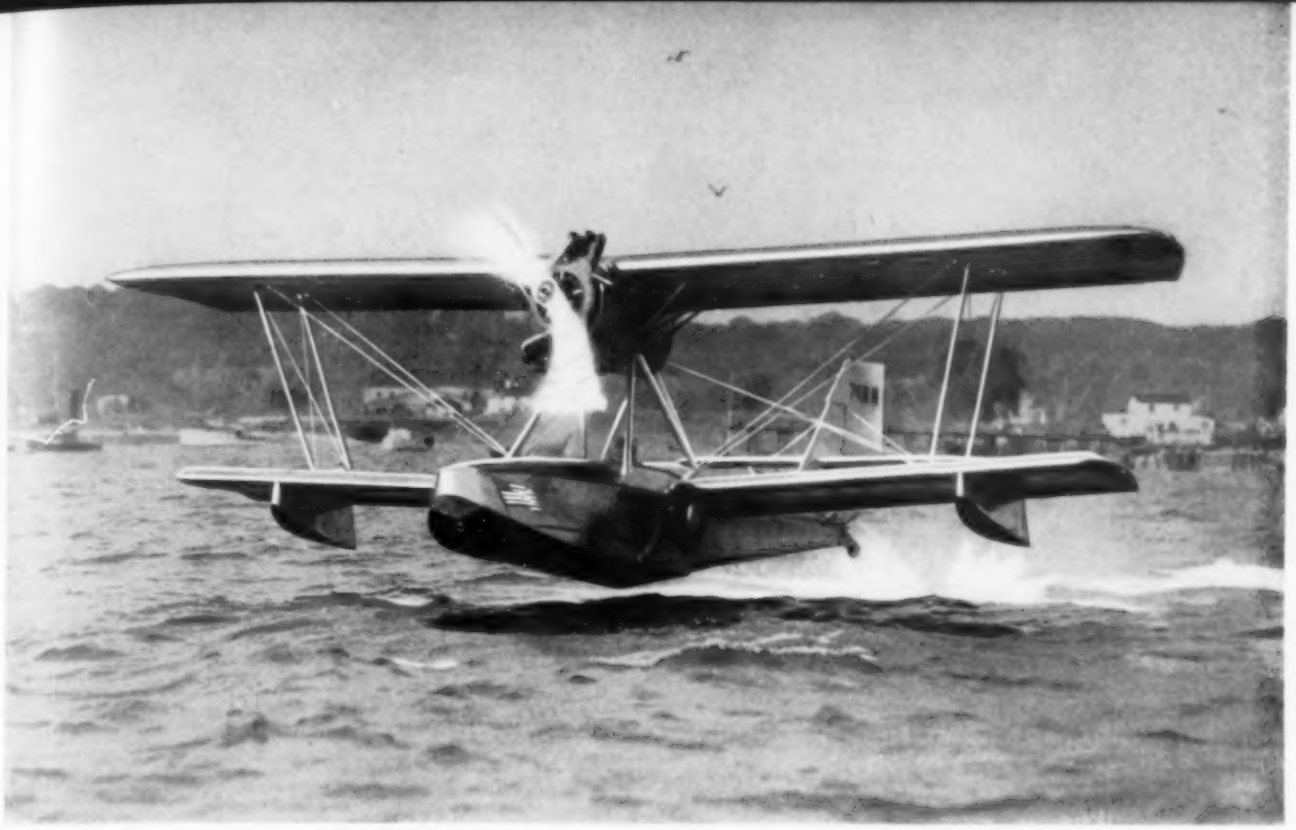
Chief concern relates to design. The thinner the metal, the greater must be the ingenuity applied in its use. But there is no longer any great secret about how to proceed in order to compensate for thinness. It is all a question of unsupported surfaces. A thin piece of paper, for instance, will lie flat on an egg crate whereas a thick blotter of the same area may not even support its own weight when held at its ends. There is also the further example of making the piece of paper stand on edge by creasing it. This creasing can be continued until the paper will actually carry a super-imposed load.

But, simple as may be the expedient, its reduction to practice involves a thorough research and the testing of every sample structure. The prospect of any such program is apt to be frightening, especially to commercial aircraft companies whose research has already been so disproportionate to their business. Furthermore, any research in a new field becomes expensive and even futile unless it is inspired by enthusiasm and is certain of managerial support. Stainless steel has had two active developments by enthusiasts. It has had half a dozen or more attempted developments by concerns which were either not in a position to complete the programs, or did not carry them to a commercial conclusion. Actually, the amount of work done and the information already available offer a surprisingly well developed background — certainly a sufficient one to encourage belief that the construction of modern airplanes in stainless steel is today not only feasible but strongly indicated.

In this connection it is well to remember that structural materials are not changed for mere whim nor to accommodate the ideas of some enthusiast. There must be some demonstrable and definite reason for a substitution of one substance for another. Thus, there *was* good reason for going from wood to all-metal; the material change actually followed a change of commercial conditions. At first, the foremost consideration of aircraft was flight, let the cost and other considerations be what they may. Next came production, and with it many radical improvements in design. In this phase of the development a long serviceable life was not a consideration, for obsolescence preceded wear-out. Now we approach stability, both of type and of production. A long useful life



When Stainless Steel Permits Gage Reductions of From One-Third to One-Tenth Those Used in Mild Steel, a New Type Structure Becomes Necessary. The one illustrated is an instance. It is novel to railroad practice and is the result of analysis, design and calculation by aircraft engineers, using aircraft methods and adapting these to railroad requirements



"The Pioneer," the First Stainless Steel, Welded Airplane. Built in 1931 and patterned after an all-wood Savoia-Marchetti, it showed greater capacity and better performance

is one item; a lowered cost is the other. Stainless steel seems to favor both. Its resistance to corrosion is important to the one and the newly developed technique of application is determining in the other.

Granting this, the argument usually degenerates from one of basic principle to a minutae of methods or selective experience. *Methods* imply special structural designs and the use of welding instead of rivets; *experience* indicates that stainless steel is corrosion resistant in spite of certain incidents where this fact is seemingly contradicted. After these matters are disposed of, the argument boils down to a matter of personal urge for or against the metal. Under this influence, facts and figures are apt to assume different significance. The fact may be accepted and the explanation neglected.

Commercial Trends Influence Use

If, therefore, stainless steel is to find a wider application in aircraft, it will come through an urge to use it. Urge is usually a managerial function and management responds to trends rather than to technical discussion. The definite trends today are commercial; they involve maintenance and cost of production. Stainless steel will find its appeal, therefore, through

1. Its inherent resistance to corrosion; its inherent stability.
2. A lower metal cost; being 30¢ a pound against from 35 to 60¢ for duralumin or Alclad.
3. Welding as against riveting; both efficiency and cost favor welding — a recognized method of mass production.
4. The fact that welding permits use of unskilled labor.
5. Stainless is fabricated as it comes from the mill; no heat treatment is required in the fabricator's shop.
6. An alternative source of supply for an essential industry, essential both in peace and war.

All of these items are commercial, and so they should be. Aviation is no longer a discovery nor a pioneering movement — it is a business. If that business calls for a new material, that material will be weighed in the commercial as well as in the technical scales. Fortunately, both measures have been taken — true, not in aviation, but nevertheless in lightweight construction. The Budd company alone has fabricated over three million pounds of 18-8 into engineered structures. It has established not only the structural worth of the material, but has further demonstrated an economic utility in a field where competition has been with mild steel, a metal costing one tenth that of stainless rather than being substantially cheaper, as it is with respect to the light alloys.

A RESEARCH LABORATORY FOR METALS

By William P. Woodside
Vice-President
Climax Molybdenum Co. of Michigan
Detroit, Michigan
National Treasurer

As one approaches a severely simple building with graystone facade and stainless steel cornice, set behind a smooth green lawn, a refreshing sight in an industrial region, and reads "Climax Molybdenum Company of Michigan" in large bronze letters set on a background of stainless steel, he instinctively feels that here is a modern institution for the solution of today's and tomorrow's industrial problems. Its builders have attempted to do just that, having had clearly in mind the enormous development of molybdenum as an alloying element which has occurred in the last two decades, and the chronic overcrowding of the old laboratory facilities. It was designed by Clair W. Ditchy, who harmonized numberless suggestions from all members of our organization, especially utilizing information gathered by Woodside, Herzig and Parke on an extended tour among metallurgical research laboratories as well as university laboratories.

The visitor might well pass quickly through the building to the furnace room at the rear, where most of the projects get under way, once they are organized in the front office. It is approximately 60x85 ft. in area, and has high clearance to the bottom chord of roof trusses. Glass is extensively used in walls otherwise tiled. The room is heated independently, by recirculated air, with fin-type heaters properly placed here and there; thus the air conditioning plant for the rest of the building is not overtaxed either with furnace smoke in the winter or with surplus heat in the summer.

Experimenting equipment installed in this room is designed to make any alloy in quantity from one pound up to 500 per heat. Very small melts are made in an Ajax-Northrup induction furnace (high frequency) holding a crucible 6 in. diameter by 11 in. high. Medium sized melts, up to 80 lb., are made in a Detroit rocking-type arc furnace, 12 in. by 15 in. internal dimensions, lined with alundum. A tilting furnace of the Lectromelt direct arc type is available for melts of 500 lb.; it has bottom banks of silica and the electrodes are 3 in. graphite, with automatic control.

All these furnaces are grouped so that electrical transformers can be housed in a room alongside, control equipment conveniently erected, and ingots poured on a sand bed for small sizes and in a pit with sand bottom for larger sizes. This is a safety measure in case of over-pour or spill. Ingot molds in sizes from $1\frac{1}{4}$x6 in. to $8\frac{1}{2}$x$8\frac{1}{2}$x30 in. are available — all of the split type held together by rings and wedges.

Ingots are reheated in two Standard Fuel and Engineering Co.'s gas fired furnaces, size 18x60 in., and are then forged down to bars of

Clair W. Ditchy
Architect
Elmer C. Forbes
Landscaping

correct size for the project with a Chambersburg open frame air hammer.

Heat treating equipment is also located in this room. The following furnaces heated electrically are used: One Hoskins type FH-204, one Hoskins type FR-207, one Hayes type LR-50S and one Hayes type HG-32. Each of the heat treating furnaces may be controlled by hand or by automatic equipment; all have indicating pyrometers mounted alongside, but the recording pyrometers are located at a distance in the physical testing room adjacent to the office of the metallurgist in charge.

It will be apparent that the facilities are well designed for a research into a new alloy or family of alloys. After the project is outlined and approved, a rapid survey of a number of alloys can be made in the small induction furnace. After the region of probable success is located, larger heats within these limits may be made in the Detroit rocker furnace if it is gray iron. If it is steel the expectancies in tonnage production of a selected analysis may be appraised by 500-lb. heats in the arc furnace.

Translating the Findings Into Practice

To many minds it may appear difficult, if not impossible, to project such small scale work forward and predict results in a steel plant working up charges anywhere from 20 to 200 times as large. In some ways laboratory melting is under better control than in large furnaces; to counterbalance this, unavoidable irregularities creep into the work on small lots between ingot pit and finished bar. In our experience, these tend to balance. In other words, several years of operations have shown us that the steel plant can make in tonnage production metal at least as good as we can make in the laboratory. Our results are therefore usually regarded as the average expectancies for a newly developed alloy.

We also have another guidance for our work on new steels which do not vary greatly in physical constitution or chemical composition from older ones already in tonnage production: In this event we run companion heats, one on the new alloy, one on the old. By comparing the laboratory findings on the latter with the physical properties known to characterize the same alloy produced commercially, we are able to evaluate the laboratory work on the new analysis under investigation.

In all this we are aided by skilled personnel in the persons of two key men in the furnace room. One is an experienced melter, the other is an old forge man. Both know the rule-of-thumb and tricks of their trade, but also (and very important) both know that these are to be subsidiary to any special instructions which must rigidly be followed in any set of experiments. A forge man who would fudge a reheating temperature, for instance, because he "knew" it would burn the steel would be hopeless in such a job.

The next most extensive area in the new laboratory is occupied by the experimental department. It is 42x45 ft. in area; two walls (one an outside wall, another separating the furnace room) are masonry and are tiled. The other two separate the experimental department from chemical laboratories and offices. The latter partitions are of steel, ingeniously assembled

into a very handsome finish. Much use is made of large areas of plate glass in the walls throughout all these rooms, not only improving the lighting but also lending spaciousness to the quarters. The offices have the outside walls (masonry) finished with steel clear to the ceiling, thus harmonizing exactly with the interior partitions.

The entire building, except furnace room, is completely air conditioned. Equipment for this is erected in a penthouse above the experimental department; air is introduced into the various rooms through ceiling fixtures (combination lighting and ventilating fixtures) and withdrawn through grilles let into the toeboards of side walls and partitions.

Considerable area is available in the experimental room for new or special equipment as future needs arise. At present we have ample for machining test specimens of all kinds, and making the more or less standardized physical tests — tension, torsion, impact, hardness, fatigue. A modern metallurgical microscope is mounted in a room of its own, adjacent to a polishing room and a dark room for developing photomicrographs. One important matter — storage of samples of all alloys made and studied — is taken care of in a room 7x16 ft. in area.

Chemical laboratories, two in number, are located to the north of this physical laboratory. One is about 14x16 ft. and the other 16x32 ft. Both are adequately lighted on all sides through large areas of glass. At present the work in these laboratories is functionalized, the individual ones being devoted to quantitative analysis, corrosion tests and to organic synthesis of colors and dye stuffs.

Steel furniture, cabinets, work tables and hoods, together with special analytical and test equipment have been installed for the above purposes. However, the construction of all of this department, being of sectionalized steel, even to the partitions, is adaptable to any change that future developments may require.

Offices for the principal research metallurgists as well as for the sales organization of the Climax Molybdenum Co. of Michigan, complete the layout. A room is provided for a working library and a record room for completed research projects. In view of the proximity to such important libraries as the University of Michigan's at Ann Arbor and Detroit Public Library, it is unnecessary to build up comprehensive shelves of metallurgical books, except on our own specialty.

METALS FOR LARGE STEAM TURBINES

IN AN ANNUAL REVIEW of the 1936 developments in central station steam turbines, E. R. Kauffman of the turbine division, South Philadelphia plant of Westinghouse Electric & Mfg. Co. notes that increased activity in the capital goods industries at last enables one to discern a trend in the type of turbines desired, toward units of moderate size and high inlet temperatures of 900° to 950° F. In Mr. Kauffman's words:

It is believed advisable to limit this temperature to 950° F. maximum, including swings, until some practical operating experience is obtained before going further. By using inlet temperatures of this order in condensing cycles and limiting the moisture content in the exhaust to 12%, these turbines can utilize economically pressures up to 1200 psi. without reheating.

Construction of efficient turbines has involved much special development by design engineers and metallurgists on problems surrounding the increase in inlet steam temperature. In turbine construction, the clearances between stationary and rotating parts are necessarily relatively small, and the creep of metals, that is, the rate of change of deformation, is of such value at the temperatures now encountered that it becomes a major factor in design. It is no longer merely a matter of designing parts to prevent failure, but they must be proportioned to insure the maintenance of dimensions within the desired limits throughout the life of the machine, even under the influence of creep at high temperature.

Accurate data on the creep characteristics of metals have not been available in the past and cannot be obtained except by long time tests. The subject has received a great amount of study and not until quite recently have sufficient data been available from which reliable conclusions can be reached.

Some of the most outstanding facts determined by these studies and which may give a better understanding of the problems confronting the design engineers are summarized below.

1. A characteristic feature of most available materials for temperatures below 1000° F. is that the creep progresses very rapidly at first and then more slowly. From this it is concluded that the material changes its properties in a fundamental manner with the passage of time and a test result

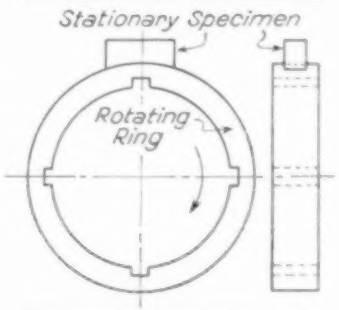
(Continued on page 324)

THE RELATIVE WEAR OF SOME HARD METALS

By Robert B. Freeman
Teaching Fellow in Mechanical Engineering
California Institute of Technology
Pasadena, California

THERE ARE NOW several hard alloys on the market that are being used in cylinder liners for engines and pumps, as well as in many other applications. The wear resistance of these materials is one of their most important properties. This paper presents the results of an investigation of sliding wear resistance of some hard alloys, made in studies at the testing materials laboratory of the Mechanical Engineering Dept. at California Institute of Technology.

Relative wear resistance of materials can be determined in the laboratory on a suitable wear testing machine which simulates the conditions to which the material is subjected in practice, and in this research a comparison of various hard metals has actually been made in tests in which they have been subjected to pure sliding friction in a bath of petroleum distillate. We desired to find the relative wear resistance of hard alloy materials in cylinder liners for diesel motors and gasoline engines; therefore it was felt that a test in which wear was accomplished by pure sliding contact would be superior to any other. Also these tests should be such that any combination of materials could be investigated, and a machine was designed so that this could be done.



Ring and Specimen in the Position Assumed in Test

Distillate was used in these tests because of its low lubricating properties and its probable similarity to actual conditions when metal-to-metal contact occurs in operation. It served to cool and maintain the test parts at a moderate temperature and in addition served the important function of washing away any abraded material. The specimens sketched below were designed so that a constant area was maintained throughout the test, thus giving a constant pressure. Also, they were small in order to be weighed accurately.

A general view of the machine is shown in the photograph on page 283. At the lower left may be seen faintly a belt from motor to pulley at the outboard end of a 2-in. steel shaft. This shaft rests on four wide-flanged disks, two at either end (the two at the near end being visible in the photograph), and these disks act as roller bearings for the rotating shaft. A revolution counter is seen above the shaft between pulley and rollers.

Near mid-length of this shaft are keyed two wearing rings of some desired metal or alloy to

be studied. These are ½ in. wide and $2\frac{7}{16}$ in. outside diameter, and are held firmly in place about 2 in. apart by locking rings. While these rings were carefully made and ground to size of one of the materials under study, no attempt was made to determine their weight losses after a test. The weighed specimens ride on these rings as shown in the line drawing, and are small blocks having a cross-sectional area ¼ x ¾ in. The surface of contact on the specimen is ground to the same radius as the ring on which it wears, the axis of curvature being parallel to the short side of the specimen. Two specimens are mounted in a special holder which in turn is bolted to the cast iron housing shown in the photograph of the testing machine. This housing straddles the shaft, and the entire load is carried by the curved surfaces of the two test blocks, through the rings on the rotating shaft, to the machine frame. Unit load between rubbing surfaces is then adjustable by counterweights and a lever system attached to the housing; an arrangement of sectors also prevents rotational movement, or shifting in any way except vertically as the supporting surface may rub away.

The holder for the two specimens is itself interesting. Each specimen is firmly gripped sidewise by water-cooled vise jaws of copper. These vises are attached to a strong bar of steel, hollow for water cooling when necessary. Mechanically a high degree of precision is necessary in order that the wear blocks may rest exactly on the ring, and set screw adjustment of each specimen and slides in the three main directions are provided. Pipe and hose connections to water and lubricant supply complete the equipment.

The wear of the small specimen was determined by its loss of weight after the run. The specimens were washed in alcohol before each weighing to remove any foreign matter. All specimens were given a first period of "wearing-in" and were thereafter weighed before and after each run. The wear on the rings was not measured, but the surface condition was closely observed.

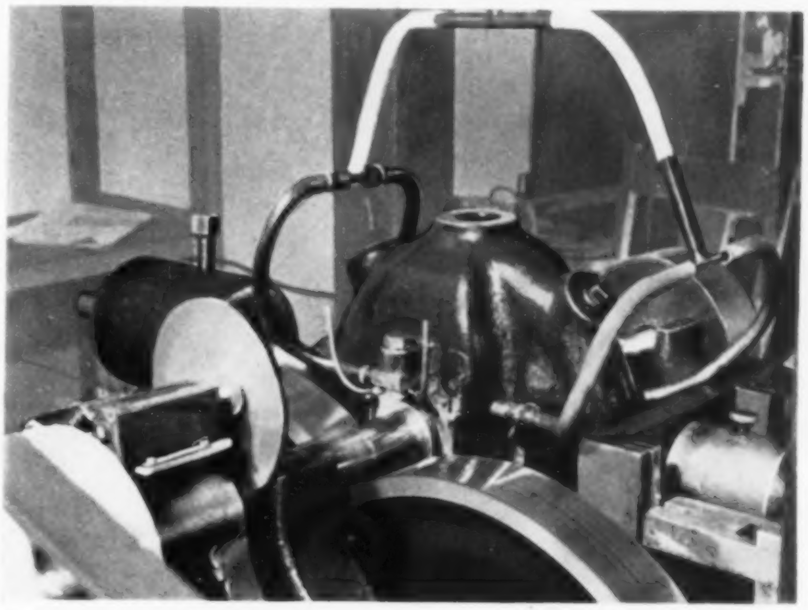
Wear Test Data Acquired

Combination	Load psi.	Speed ft./min.	Wear Factor	Condition of Specimen	Condition of Ring
A.C.I. on A.C.I.	500	393	1.4	Very smooth	Very smooth
	300	786	0.2	Very slightly galled	Smooth
	300	1180	1.6	Galled	Slightly galled
W.C.I. on W.C.I.	400	393	0.2	Smooth	Smooth
	400	786	2.6	Ridged	Ridged
	300	1180	0.5	Slightly ridged	Slightly ridged
N. on N.	300	786	3.4	Very smooth	Very slightly galled
N. on A.C.I.	300	786	0.6	Slightly ridged & galled	Very smooth & slightly ridged
A.C.I. on N.	300	786	0.2	Very slightly ridged	Slightly ridged and galled
C-H.S. on C-H.S.	300	786	34.0	Slightly ridged & galled	Slightly ridged & galled
C-H.S. on A.C.I.	300	786	0.05	Very, very smooth	Very slightly ridged
A.C.I. on C-H.S.	300	786	1.1	Smooth	Very slightly ridged & very, very slightly galled
H.st. on H.st.	300	786	45.5	Ridged	Ridged
H.st. on A.C.I.	300	786	1.0	Badly galled	Ridged
A.C.I. on H.st.	300	786	1.7	Very, very slightly galled	Smooth
W.C.I. on A.C.I.	400	786	0.1	Smooth	Smooth
A.C.I. on W.C.I.	300	1180	0.7	Badly galled	Ridged
Eng. on A.C.I.	300	786	1.5	Slightly galled	Smooth

The wear at any given load and speed depends upon the contact surface area and the length of the surface passed over. Therefore, the results of these tests were determined by dividing the loss of weight experienced by the specimen during the run by the projected area of contact and the length of travel. (The projected area of contact is the area of the specimen's cross-section.) The unit wear value thus obtained is expressed in grams per square inch per foot. To simplify the presentation of results,

the term "wear factor" has been selected which is equal to 10^5 times the loss in weight expressed in grams per square inch per foot. The higher the wear factor, the higher will be the rate of wear of the given material.

Six materials were tested: Haynes stellite (noted as H.st. in the table) an alloy principally of cobalt, chromium and tungsten; nitrided nitralloy (N.) a chromium-aluminum-molybdenum steel; a casehardened steel (C-H.S.) of unknown chemical composition; white cast iron (W.C.I.) containing 3.25% C, 0.30% Si, 0.40% Mn and 0.10% P; an engine block casting (Eng.) containing 3.38% C, 2.16% Si, 0.65% Mn, 0.05% P, 1.40% Ni, 0.45% Cr and 0.40% Mo; and an alloy cast iron (A.C.I.) containing 2.75% C, 1.00% Si, 0.80% boron, and 4.50% Ni.



General View of Wear Testing Machine. Specimens held inside cast iron housing ride on rings keyed to rotating horizontal shaft

Results of tests on these materials in various combinations are shown in the adjoining table at left.

When considering the wear of two dissimilar metals against each other, the wear of *each* must be taken into account. The tests as they were conducted in this investigation do not allow a direct evaluation of the wear resistance of a combination, but give only a value of the wear resistance of each material rubbing upon the other member of the combination. In the second table, therefore, the wear factor for the combination of materials at one speed and pressure has been computed by taking the average of the individual values for the two materials rubbing together.

Relative Wear Resistance

PRESSURE: 300 PSI.; SPEED: 786 FT. PER MIN.

Combination	Wear Factor	Ratio	Surface Conditions
A.C.I. on A.C.I.	0.20	100	Very slight galling
A.C.I. on N.	0.40	50	A.C.I. shows slight ridging and N. shows slight ridging and galling
A.C.I. on C-H.S.	0.58	35	Both very slightly ridged
A.C.I. on Eng.	0.8	25	A.C.I. shows smooth surface and Eng. shows slight galling
A.C.I. on H.st.	1.4	14	A.C.I. shows ridging and Stellite shows galling
W.C.I. on W.C.I.	2.6	8	Ridging
N. on N.	3.4	6	Very slight galling
C-H.S. on C-H.S.	34.	0.0.6	Slight ridging and galling
H.st. on H.st.	48.	0.4	Ridging

During these tests, three different types of surface conditions were observed. Specimens were either smooth, ridged, or galled after test. The smooth surfaces were mirror bright, the ridged surfaces were scored in the direction of wear, and the galled surfaces show that adhesion or cohesion of localized areas of the two mating materials had taken place.

A metallographic investigation was made of the worn surfaces. Specimens were heavily plated with copper so that a section perpendicular to the worn surface could be photographed without distortion to the very edge. The metallographic study showed that those surfaces which were smooth after test were accompanied by a microstructure which was not distorted. A typical view reproduced on page 284 shows the edge is clean cut and smooth even at high magnification. The ridged surfaces were also ac-

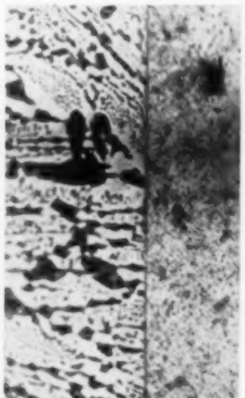
companied by a clean cut structure showing no distortion. If galling occurred, a layer of worked metal appeared, more or less cracked and pitted with sharp-edged cavities.

From further metallographic and X-ray studies, it was found that in the case of white cast iron, this layer was composed of iron carbide interspersed with small grains of pearlite showing evidence of severe working and distortion. The layer was also richer in iron carbide than the parent material. Apparently, during the process of wear, the softer pearlite grains had been squeezed from between the cementite grains. If the pearlite reached the surface, it was rubbed off by the mating surface. If it did not reach the surface of contact of the two wearing parts, it was trapped in the layer of worked carbide. This layer of hard carbide was of about the same hardness as the carbide grains in the parent metal.

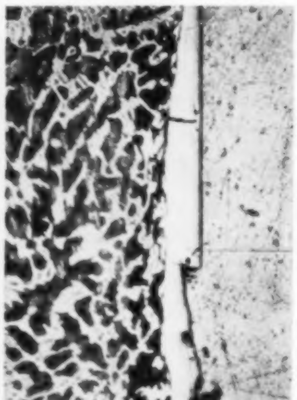
In summary, tests and apparatus have been described by which the relative sliding wear resistance of some hard alloys has been determined. The surface conditions accompanying wear have been shown with photomicrographs of the worn edge. Both smooth and ridged surfaces were accompanied by a structure which was undistorted and smooth even under the microscope. The galled surfaces were accompanied by a worked layer of hard material, which, in the case of white cast iron, was shown to consist of iron carbide with small grains of pearlite interspersed throughout.

The author wishes to express his appreciation to the Industrial Research Laboratories of Los Angeles for assistance in this investigation. Gratitude is also extended to Dr. Donald S. Clark of the California Institute of Technology, under whose direction this work was done.

Undistorted, clean cut surface worn smooth



Undistorted, surface worn in shallow ridges



Layer of Cementite over distorted grains on galled surface

Typical Structures After Test (Copper Plate at Right in All Views)

MAGNETIC ALLOYS OF IRON, NICKEL, COBALT

By Gustaf W. Elmen

Abstract from Electrical Engineering, Vol. 54, p. 1292

SOME ALLOYS have remarkable magnetic characteristics which are not predictable or even explainable. Consequently a systematic study of the iron-nickel-cobalt system has been made in the Bell Telephone Laboratories. In the course of this investigation several thousand specimens were made and tested in a period extending over 15 years. It has been justified by the large number of alloys it has developed for use in communication engineering.

A great many factors contribute to the final properties of an alloy. Among the most important of these are the purity of the elements used in the alloy, their preparation, and the heat treatment. For iron and the magnetic alloys the magnetic properties can be improved materially by removing extremely small quantities of carbon and other non-metallic elements through heat treating in an atmosphere of hydrogen and at temperatures close to the melting point. For communication purposes, it has not been found commercially expedient as yet to introduce this method of refinement; the purity of the constituents of manufactured alloys is controlled by ordinary methods of chemical analysis, by methods of melting, and by annealing processes that do not increase the amounts of important impurities. The magnetic properties here recorded have been obtained on materials produced by such commercial metallurgical methods.

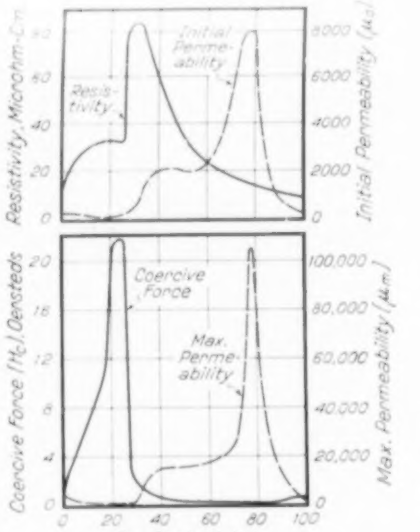
It was early found that some alloys required special heat treatments such as a rapid cooling, an extremely slow cooling, or soaking at a high temperature. Three methods of heat treatment that, in a general way, would separate the alloys into groups, were developed.

(1) *Annealing* consists of heating the samples in closed containers to 1000° C. (1835° F.) and cooling with the furnace, ordinarily requiring 7 hr. before room temperature is reached. This is primarily for the purpose of removing mechanical strains from rolling and stamping into suitable shapes. *(Continued on page 326)*

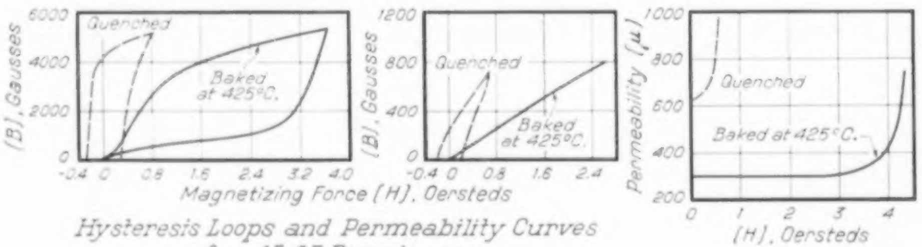
Composition and Magnetic Relationships of Modern Alloys

From "Magnetic Alloys of Iron, Nickel and Cobalt" by G. W. Elmen; 1936 Convention, A.I.E.E.

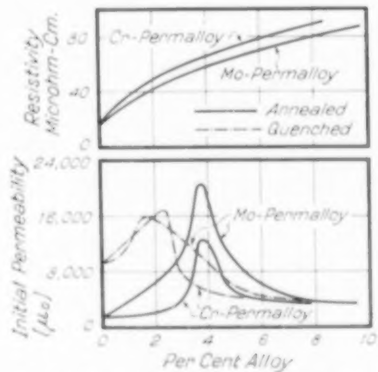
Code	Designation	Chemical Composition				Permeability		Hysteresis Loss at Saturation	Residual Induction	Coercive Force	Saturation of Intrinsic Induction	Resistivity
		Ni	Fe	Co	Others	Initial	Maximum					
A	78.5 permalloy	78.5	21.5	—	—	10,000	105,000	200	6,000	0.05	10,700	16
B	3.8-78.5 Mo-permalloy	78.5	17.7	—	3.8 Mo	20,000	75,000	200	5,000	0.05	8,500	55
C	3.8-78.5 Cr-permalloy	78.5	17.7	—	3.8 Cr	12,000	62,000	200	4,500	0.05	8,000	65
D	45 permalloy	45	55	—	—	2,700	23,000	1,200	8,000	0.3	16,000	45
E	4% silicon steel	—	—	—	—	600	6 000	3,500	12,000	0.5	20,000	50
F	Armco iron	—	—	—	—	250	7,000	5,000	13,000	1.0	22,000	11
G	Permendur	—	50	50	—	700	2,900	6,000	14,000	1.0	24,000	6
H	7-45-25 Mo-perminvar (baked)	45	23	25	7 Mo	550	3,700	2,600	4,300	0.65	10,300	80
I	45-25 perminvar (baked)	45	30	25	—	400	2,000	2,500	3,000	1.2	15,500	19



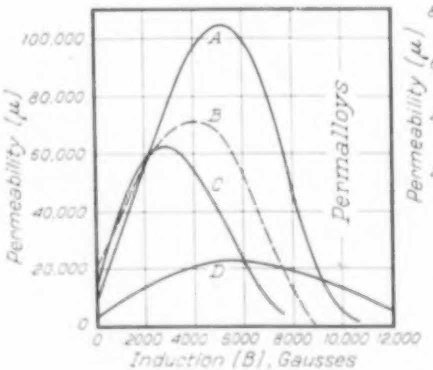
'Magnetic Properties of Fe-Ni Alloys

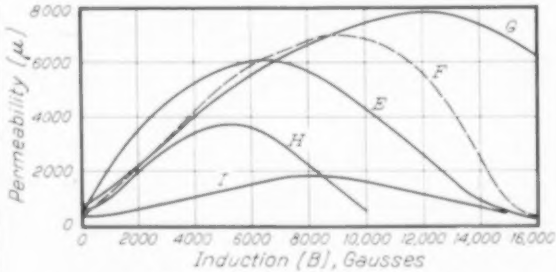


Hysteresis Loops and Permeability Curves for 45-25 Perminvar

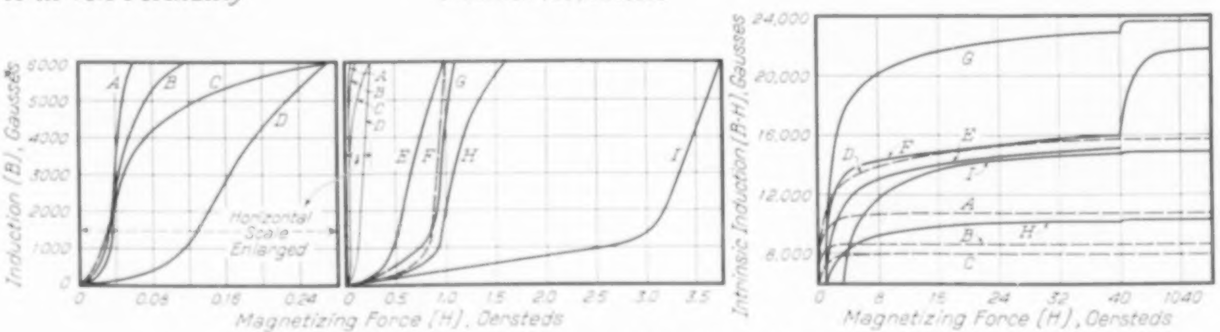


Effect of Replacing Fe With Cr or Mo in 78.5 Permalloy

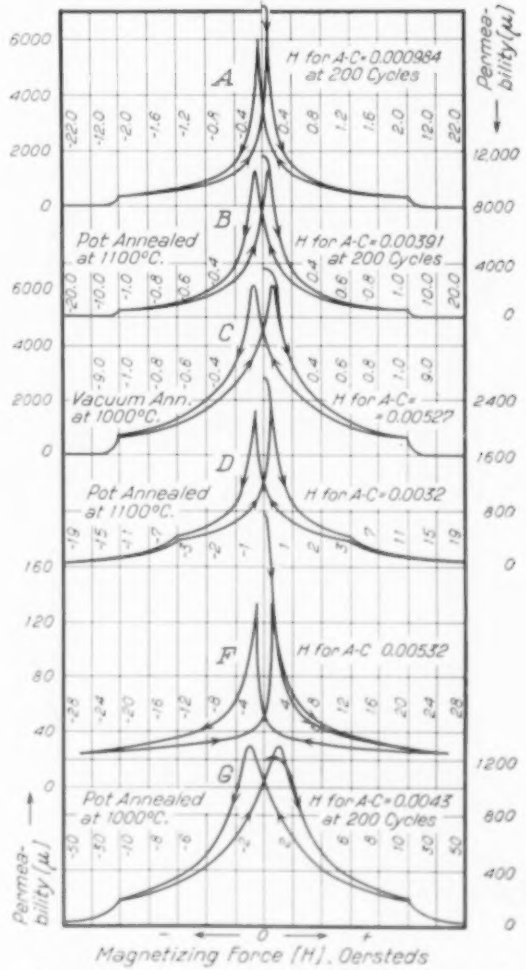




Permeability Curves of Permalloys and Other Magnetic Materials



Magnetization Curves at Low and High Flux Densities



Effect of Superposed D.C. Fields on A.C. Permeability (Furnace Cooled After 1hr. at Temp. Noted)

CORRESPONDENCE..

..AND FOREIGN LETTERS

THE CRITICAL TEMPERATURE IN HIGH CHROMIUM IRONS & STEELS

Special letter to METAL PROGRESS

by J. H. G. Monypenny
Author of "Stainless Iron and Steel"

SHEFFIELD, ENGLAND — Most of the alloys that are used to obtain improved properties in steel are added to the latter in relatively small proportions, but four of them at least — chromium, nickel, manganese and tungsten — are also frequently used in much larger amounts. This applies particularly to chromium, which is the essential alloy in the production of the so-called "stainless" or "corrosion resisting" steels, and hence it is of considerable practical importance that the effect of increasing quantities of this metal on the structural conditions of steel should be known with a fair degree of accuracy.

As one intimately concerned in the commercial production of corrosion resisting steels, the writer recently surveyed the rather voluminous literature which has been published regarding the structure and constitution of iron-carbon-chromium alloys, to see whether it was possible to indicate with a reasonable degree of accuracy the probable form of that corner of the ternary model containing up to about 30% chromium and 2% carbon. The outstanding impressions which he obtained while preparing that survey (published in a paper forming Section IV of the first report of the Alloy Steel Research Committee of the British Iron and Steel Institute, issued last September) were, firstly, the lack of information which still exists regarding the precise effect of chromium on the temperatures at which several fundamentally important structural changes occur in steel, or even the exact course of some of these changes in the presence of chromium and, secondly, the lack of agreement in the results of different investigations of this subject. The writer's conclusions, as a result of his survey were:

1. Up to about 12% chromium and 2% carbon the trends of the structural changes are known with fair accuracy, but much more information is required as to details — temperatures and concentrations — before an accurate ternary model can be drawn.

2. Above 12% chromium certain trends in structural changes have been investigated, but, with the information available at present, a section at 20% chromium can only be drawn approximately, and much more data are required before the probable shape of sections at high chromium contents can be sketched with any degree of certainty.

3. Most, if not all, of the published data on alloys containing carbon has been obtained from material of good commercial quality, but none from what may be termed pure alloys. It is possible that such impurities as are present in the commercial samples may have an appreciable effect on structural conditions. There is need, therefore, for the systematic investigation of pure alloys.

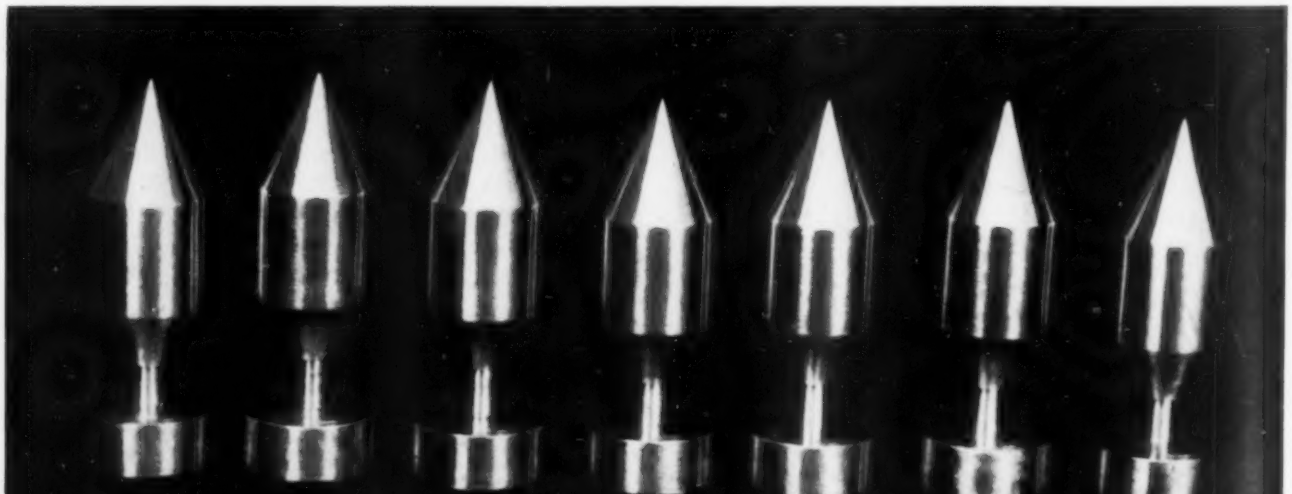
For the details on which these conclusions were based, the reader may refer to the actual paper, but it may be of interest to consider briefly the results regarding one of the main features of the diagram, namely the pearlite → austenite change at Ac_1.

As was to be expected, the effect of chromium on the temperature at which this change from pearlite to austenite takes place has received attention at the hands of many investigators. The results obtained on steels containing up to about 12% chromium show variations of 50 to 70° F., and it seems probable that much of

this variation is due to the failure of some investigators to appreciate fully the sluggish manner in which this change occurs in chromium steels.

It may be well to emphasize the fact, pointed out by the writer over 16 years ago, that part of the carbide that forms the pearlite in hypo-eutectoid steels containing 10 or 12% chromium may still remain out of solution even after heating for 30 min. at 200° or so above the Ac_1 temperature of the steel as recorded on a thermal curve. Incidentally, the latter temperature may quite easily be 40 or 50° (F.) above that at which carbide definitely begins to dissolve, with the production of austenite, at much slower rates of heating. The striking persistence of these carbide particles also raises the question as to whether Ac_1 will actually take place at some *definite* temperature in these steels if they are heated very slowly or whether it will occur over a *range* of temperatures even under these conditions. Krivobok has suggested the latter on theoretical grounds, and quite probably it is the correct view. At the same time it may be mentioned that no direct evidence of the simultaneous presence of ferrite, austenite and carbide in equilibrium over a range of temperature in chromium steels of eutectoid composition has yet been obtained, so far as the writer is aware and, also, that the shape of the curve connecting Brinell hardness values of quenched samples of such steels with quenching temperatures suggests that the temperature range in which ferrite may exist in such equilibrium cannot be great. The matter, however, should provide an attractive subject for more precise investigation!

Matters are even more complex when chromium exceeds about 12%. The Ac_1 change becomes still more sluggish, at least in steels low in carbon, and hence the difficulties of determining its true position increase considerably. The cause for this extra sluggishness is understandable; if the ferrite, which forms part of the structure of these steels in the annealed and fully tempered conditions, contains more than about 12% chromium in solution (which is not always the case in steels of high carbon content) it has no tendency to change to the gamma form, except as this transformation may be induced in it by solution of carbon or of certain impurities; on the contrary, if unaffected by external



Test Specimens of Cast Corrosion Resistant Steel After 500 Hr. Exposure to Salt Spray

influences, it would remain in the alpha form up to the melting point. It is not surprising, therefore, that austenite forms but slowly in steel containing such ferrite.

Much less information is available regarding the position of Ac_1 in these high chromium steels, and it is certain that some of the published diagrams are quite wrong and misleading. In at least two examples, the lines purporting to represent the position of Ac_1 in sections through the ternary model at stated chromium contents, actually marked not this point but the lowest quenching temperature from which retained austenite was mainly obtained, instead of martensite, and in some of the steels examined, the temperature so recorded is 350° F. or so above the true value of Ac_1.

If Ac_1 temperatures are determined by methods involving a slow rate of heating or by the examination of a series of quenched samples held at their respective quenching temperatures for periods of 30 to 60 min., the results show beyond doubt that, for a given percentage of chromium, the temperature falls as carbon content rises. For example, at 20% chromium, the values appear to be substantially as follows:

Carbon Content	Ac_1 Temperature	
0.10%	1800° F.	970° C.
0.30%	1620° F.	880° C.
0.50%	1530° F.	830° C.
0.70%	1500° F.	810° C.

This dependence on carbon content as well as chromium was pointed out nearly ten years ago by Kalling who suggested, probably correctly, that Ac_1 temperatures in these steels were a function of the chromium content of their ferrite in the annealed or fully tempered condition, and actually rose very sharply when this chromium content exceeded about 16%. It is obvious, of course, that in steels containing a stated amount of chromium, the content of the latter in the ferrite will fall with increasing carbon content, since the carbide formed is substantially chromium carbide.

Whether the relatively high transformation temperatures thus obtained for the lower carbon steels would be lowered appreciably by extremely slow rates of heating, is a matter which requires further investigation, but it seems very doubtful whether even such conditions would reduce the Ac_1 temperatures of these low carbon materials to those of higher carbon steels of equal chromium content.

Attention has been restricted, in this letter, to the effect of chromium on the Ac_1 change. Actually, more information appears to have been published on this particular change than on any other in chromium steels. It may be suggested, therefore, without fear of contradiction that there is a pressing need for further investigation regarding the constitution of these very important iron-carbon-chromium alloys.

J. H. G. Monypenny

MANUFACTURE AND PROPERTIES OF CENTRIFUGAL-CAST PIPE

Special letter to Metal Progress

by Federico Giolitti
Bessemer Medallist

Turin, Italy — Most of the numerous patents covering various processes and machines for the centrifugal casting of iron pipe have not yet found important industrial applications in Europe. The only ones used on a very large scale are those covered by the patents taken by Delavaud, by Arens and by Moore.

The Moore process, which uses molds lined with refractory, is very seldom used in Italy. It is generally believed by my countrymen that the loss of time necessitated by frequent change of molds and the slower solidification and cooling of the iron reduces the output of a given machine to about one half the production obtainable when using metallic molds (other conditions being substantially equal). The advantages of sand-lined molds (such as the simplification of the pouring operation, the total or partial elimination of reheating or annealing of the castings) seem to be generally counterbalanced by the economic disadvantage of a smaller output, and the technical inferiority of non-annealed pipe.

The results obtained in a large, new plant of the Ilva Company at Cogoleto seem to confirm completely these opinions.

The machines installed in this plant are of the Arens type, with many interesting improvements. The output of the small machines

— making pipe up to 10 ft. long and 3½ in. diameter — can easily exceed 30 pieces an hour. Medium-sized machines can cast from 10 to 12 pipes per hour, 13 ft. long and 18 in. diameter. These outputs are considerably larger than those generally obtained in Italy with machines using sand-lined molds, and this leaves ample margins for the expenses incident to reheating. In fact, when annealing is done, as in the Ilva plant, in modern, automatic, continuous, oil-fired furnaces of about 200 tons capacity per day, the oil consumption does not exceed 2.2% of the weight of reheated pipe, and the total cost of labor, including all handling, remains below 80 centimes of lira per ton (100 lira = $5.30 at current exchange).

It has been amply demonstrated, I think, that the quality of chill-cast pipe, carefully reheated, is far superior to the quality of sand-cast pipe, especially on account of the great reduction of liquation processes during rapid solidification, and the complete elimination of internal stresses by annealing. This last condition is becoming constantly more important, with the increasing technical requirements specified by users. Complete researches on this last subject have been published recently by Mr. Aurelj, superintendent of the Ilva plant.

To give an idea of the average bursting resistance of ordinary pipe made in the European plants working under the conditions here outlined, I will summarize results of tests carried to rupture by internal hydraulic pressure on pipes of different sizes.

Medium sized pipe, 6 to 8 in. diameter, 0.30 in. wall thickness, burst at 160 to 190 atmospheres, and developed tensile strength (computed) of 26,000 to 36,000 psi.

Short lengths of the larger pipe, about 14 in. diameter, 0.55 in. wall thickness, more or less, burst at 165 to 190 atmospheres, corresponding to 30,000 to 33,000 psi. ultimate tensile strength.

Large pipe, 17 to 18 in. diameter, 0.47 to 0.55 in. wall thickness, burst at 112 to 130 atmospheres (depending on their thickness) and developed about 29,000 psi. ultimate strength.

Extra heavy pipe, 18 in. outside diameter, 0.86 in. wall thickness, tested in 5-ft. sections, burst at an average of 192 atmospheres, or a computed ultimate strength of 25,500 psi.

The above data refer to ordinary cupola iron. Most of the present specifications cannot be met with such material, and the use of higher quality iron, melted in electric or revolving furnaces, is gaining ground every day in the plants manufacturing centrifugal-cast pipe.

FEDERICO GIOLITTI

CONTROL OF FUSION WELDING BY MECHANICAL TESTS

Special letter to METAL PROGRESS

by Albert M. Portevin
Director, Fusion Welding Institute

PARIS, FRANCE — Fusion welding with arc and blowpipe is making rapid progress and is being used for a wide variety of applications, some of them with very rigid requirements. The problem of control is therefore important and should be studied in all its aspects and at all stages of the operation, before, during, and after execution of the welding process. Such control may be summed up in the following table:

I. Before execution of the welding process:
   1. Control of raw materials
      - Metal to be joined (weldability)
      - Addition metal (welding rod or electrode)
      - Equipment (blowpipes, regulators, welding machines.)
   2. Education and testing of operators (proof welding)

II. During the welding process (including preparation of the part to be welded):
   - Rules, methods and standards for preparation and execution of welding, and the supervision of the operation.

III. After the welding process; tests of the finished assembly:
   1. Non-destructive tests (visual inspection and physical methods such as X-rays, gamma rays, magnetic tests, and sound tests)
   2. Tests on samples, either made separately during the operation, or taken from the finished assembly which can then be repaired.

Such control can be exercised either by mechanical tests ending in the examination of

fractures or by non-destructive tests of physical characteristics such as micrographic or corrosion tests.

The following remarks should be made concerning the use of mechanical testing methods:

1. Tests of the filler rod or electrodes before welding:

Mechanical tests before use have no significance since the addition metal is used after fusion; only the chemical analysis is useful.

Mechanical testing of metal from the joint should include impact tests if the metal is susceptible to brittleness on superheating, such as ferritic metals (alpha iron). Notch brittleness is associated with hardness, shearing strength or tensile strength, so in some cases one or more of the latter will be informative.

Results will vary considerably, and it is therefore recommended that repeated tests be made and the results interpreted by statistical analysis. However, it must not be forgotten that the mechanical properties depend on the *conditions* of deposition, and in order to obtain test pieces of the usual dimensions, heavy deposits of weld metal must be made under conditions quite different from ordinary work. To obtain comparable values in all particulars, it would be necessary to weld normally and take micro test pieces from the joints. (METAL PROGRESS, July 1935, page 49.)

2. Control before welding of the metal to be welded — weldability:

Because of the physical and chemical changes during fusion, a thorough study of the metals to be welded must be made to determine weldability (as we pointed out in METAL PROGRESS, Nov. 1933, page 45) by means of micro test pieces and micro testing machines.

3. Test welds; control of personnel:

Since in this case it is mostly a question of bringing to light defects in welding technique, tensile and bend tests are generally used, depending on the conditions and the equipment available. Of course this preliminary testing of welders has no absolute value except for eliminating incompetent persons, since a well-made weld does not necessarily indicate the quality of the one to follow. We might cite as an example a fatal accident to a hydraulic conduit, burst because of poorly made welds, although the proof welds, performed by the same personnel, did not present these defects.

4. Tests of welded structures and welded parts after welding:

From the viewpoint of the security of welded structures, it is essential first to avoid physical defects, discontinuities, inclusions, and adhesions. There are only two ways to do this:

First by control of the welding personnel during the welding process, insuring that best practices are carefully followed. This should be under the supervision of very experienced and conscientious persons.

Second by non-destructive tests of the complete structure. Present practice, based on experience and precedent, is to rely on visual tests, magnetic examinations, and radiography. Again this should always be done by most experienced persons.

Magnetographic examination ("magnaflux") has been perfected and made much more sensitive by the use of impalpable powders in suspension in a liquid applied directly on the piece. X-ray inspection has also made considerable progress, as much in the thickness that can be penetrated as in the perfection and clearness

Large Cylindrical Tank Assembled by Tack Welding, Placed on Rollers and Under an Adjustable Overhead Track Carrying an Automatic Welding Head. All circumferential and longitudinal seams can be completed in this set-up. Courtesy Lincoln Electric Co.

of the photographs obtained. X-ray inspection eliminates poor welds but does not give absolute security, since its sensitivity depends on the thickness of the defect or void, while the seriousness of the defect depends on its extent and the sharpness of its edges. Thus, a spherical cavity, easily visible under X-rays, is a much less serious defect than an internal fissure or adhesion of the same extent but without noticeable thickness and consequently invisible under X-rays. In short, this method reveals defects of three dimensions, while defects of two dimensions are the most serious.

This relative lack of non-destructive tests emphasizes the value of good welding personnel and control during welding; it is advisable, when possible, to eliminate the personal equation by using automatic welding processes (although this of course does not automatically give perfect joints).

Models or small scale assemblies welded especially for testing are useful only for study and comparison to determine the behavior of a metal, an electrode, a type of weld or a certain welding method. From the point of view of control and security of a full-sized structure, however, such studies can never be anything but a different piece from the structure to be tested.

The mechanical properties of a joint will only be comparable to those of the structure when all the factors — chemical, metallurgical and thermal — are the same. These conditions are filled when a test piece is taken from a series of identical pieces welded in the same manner.

In order to obtain the actual specific mechanical properties of the structure, the structure itself must be tested, either as a whole (remaining within the bounds of elastic deformation) or, as mentioned above, by carefully chosen samples. Elastic tests on the entire structure can furnish information by comparing the deformation experimentally determined with the deformation which can be calculated in advance. As to control by test pieces, this method is not in use at present to any extent in France; however, as mentioned above, the use of micro test pieces and micro testing machines may lead to new advances along this line.

Albert Portevin

NON-TARNISHING SILVER PLATE MADE BY ALLOYING

Special letter to Metal Progress

by C. C. Downie
Specialist in Rare Metals

Glasgow, Scotland — Silver plated goods have suffered considerably by the competition offered by different chromium platings, which, unlike those of silver, do not tarnish and necessitate frequent polishing. This competition has lately become so severe that the complete elimination of silver from tableware was contemplated.

It would appear difficult at first sight to understand the general public purchasing comparatively expensive silver plated goods, when the much more economical chromium plated products are available, but there are always those persons in a community who prefer a select and distinctive product that will attract attention. So long as silver plated goods required continual polishing, little advantage could be claimed in possessing expensive tableware; on the contrary, the latter came in for considerable ridicule.

With the supremacy of the automobile in world popularity, precious metals for jewelry, decorative work or tableware have decreased in demand, and the manufacturers of such products had no alternative but to curtail their activities. In order to alleviate the situation, platinum was replaced by white gold and the comparatively inexpensive plated platinum and platinum alloys. The latter received commercial application for telescope manufacture, until indium platings were proved to insure a more perfect reflection.

A short survey of the subject is sufficient to reveal that wherever precious metals are employed, the modern tendency is to substitute one of the less common metals, and thus reduce cost. Silver plating, however, stands a good chance of regaining its earlier popularity, provided the ordinary tarnishing is overcome.

Tarnishing and discoloration of silver can be prevented by introduction of small quantities of metals of the platinum group — namely, platinum, rhodium and iridium. Such silver plated

goods possess a highly attractive appearance, and the mirror-like surface does not require polishing, but remains more or less permanent.

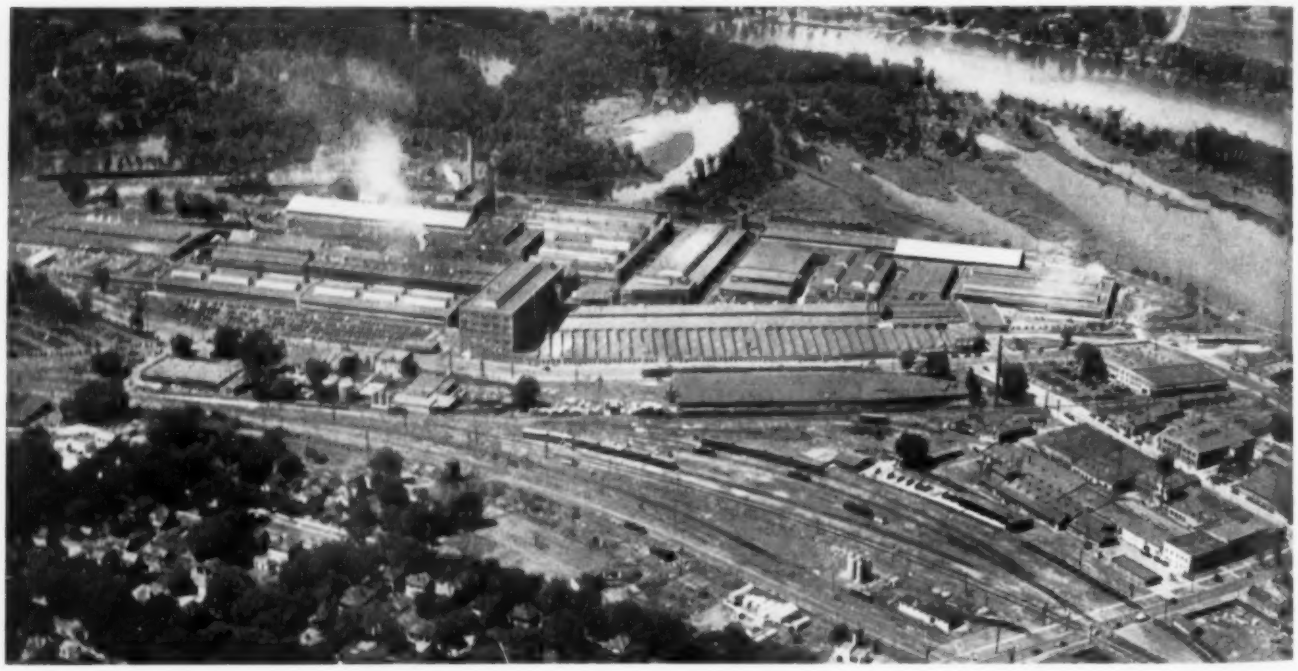
Probably rhodium has been given most attention, since it possesses a much lower specific gravity than platinum or iridium, and thus can provide a greater surface per unit of metal.

In the electroplating process, the preparation of an anode of silver with rhodium, iridium or platinum carried the practical difficulty that the latter metals melt at very high temperatures. There was thus little alternative but to use prepared electrolytes, and by dint of continuous circulation and careful current control, silver anodes were immersed in prepared electrolytes of the rare additions whereby an alloy was deposited on the tableware cathodes. The electrolytes first used consisted of nitrites and hyponitrites, which were protected by patent, but later research revealed that other salts of "hypo" acids would furnish equally satisfactory results.

Although it is known that the setting up of over-voltages and other resistances can retard the progress of any electrolytic deposition, such actions are more pronounced when the anode is of one metal and the electrolyte contains another. This special silver plating is therefore kept under analytical control throughout. All the platinum metals are comparatively simple to deposit electrolytically, so that although conditions are more exacting for plating silver containing a rare metal addition, they are by no means complicated.

This silver alloy plating has found application for microscope reflectors, but the chief hope is to regain the market for cutlery and general tableware, much of which has been lost to chromium plated goods. Although not comparable to indium platings, these silver-rare-alloy plates are comparatively cheap, and whiter than chromium plate, thus enhancing the general appearance of the reflection.

C. C. Downie



The air-view on page 175 of last month's Metal Progress was the Cuyahoga Works of the American Steel & Wire Co. at Cleveland with the Aluminum Co. of America in the background. Many correct identifications were received, the first six being William J. Diekmann, Chicago, W. T. Askin, Cleveland, Alex Rexion, Cleveland, Cornelius Benkoe, Cleveland, F. P. Whalen, Kearny, N. J., and Roy E. Paine, Oakland, Calif. Identify this metal working plant immediately, and get an enlarged, framed reproduction.

PERSONALS

Hyman Bornstein ⊕, Deere & Co., Moline, Ill., has been nominated for president of the American Foundrymen's Association. **Marshall Post**, Birdsboro Foundry & Machine Co., has been nominated for vice-president, and **Duncan P. Forbes** ⊕, Gunite Foundries Corp.; **H. B. Hanley**, American Laundry Machinery Co.; **C. J. P. Hoehn**, Enterprise Foundry Co.; **Thomas Kaveny**, Herman Pneumatic Machine Co.; **James L. Wick, Jr.**, Falcon Bronze Co.; and **C. E. Sims** ⊕, Battelle Memorial Institute, have been nominated for directors.

Harry T. Woolson, executive engineer, Chrysler Corp., has been elected president of the Society of Automotive Engineers for 1937.

Charles E. MacQuigg ⊕, director of engineering, Union Carbide & Carbon Co., has been made dean of the college of engineering of Ohio State University, effective July 1.

A. J. Field ⊕, for the past 7 years consulting engineer for Arthur Seligman & Co., New York, has returned to England to assume an important post at the works of the British Aluminium Co., Ltd.

B. L. McCarthy ⊕, metallurgist, Wickwire Spencer Steel Co., Buffalo, has been appointed chairman of a new division of the Wire Association devoted to cold working of metals and cold finished products. **A. R. Zapp**, Firth-Sterling Steel Co. has been appointed chairman of the Organization and Membership Committee.

George H. Bitzer ⊕ has been made eastern representative of Forging & Casting Corp., Ferndale, Mich., with offices in Pittsburgh.

R. H. Barnes ⊕ has been appointed field metallurgist for the Cleveland district, American Steel & Wire Co.

Paul D. Merica ⊕, vice-president, International Nickel Co., Inc., delivered the Howe Memorial Lecture of the American Institute of Mining and Metallurgical Engineers on Feb. 18.

James W. Poynter ⊕ resigned from American Rolling Mill Co. to take a position as junior metallurgist at Wright Field, Dayton, Ohio.

L. A. Shea ⊕, formerly Chicago district manager for Hevi Duty Electric Co., has been made assistant sales manager for Lindberg Engineering Co.

Walter M. Saunders, Jr. ⊕ has been made president of the New England Foundrymen's Association.

PERSONALS

L. E. Murphy has retired from active service as chairman of the board for E. F. Houghton & Co. He will continue as a director.

John Fulton has left Bethlehem Steel Co. to become a sales engineer in the Newark branch of Wheelock, Lovejoy & Co., Inc.

A. W. Gregg has resigned as works manager for Farrell-Cheek Steel Co. to become foundry engineer in the Industrial Sales Division of Whiting Corp., Harvey, Ill.

Ashburne Oliver resident material inspector at Pittsburgh for the Norfolk & Western Railway Co., has been transferred to Roanoke, Va., as assistant engineer of tests.

F. Lloyd Woodside, formerly of Ludlum Steel Co., is now connected with the research laboratories of the Climax Molybdenum Co. of Michigan at Detroit.

H. F. Brown has accepted a position with Standard Oil Development Co. at Bayway Refinery, Linden, N. J.

Charles B. Pharo, Jr. has been transferred to the Sales Promotion Department of Republic Steel Corp., Cleveland.

Mitchell P. Christensen has resigned as metallurgist at Rock Island Arsenal to open a consulting office in Chicago.

Ralph O. Griffis, formerly sheet metallurgist at Youngstown Sheet & Tube Co., is now research engineer, Development & Research Department, Bethlehem Steel Co., Bethlehem, Pa.

Stanley T. Johnson has a position with Carnegie-Illinois Steel Corp. at Pittsburgh as observer in the Homestead plant.

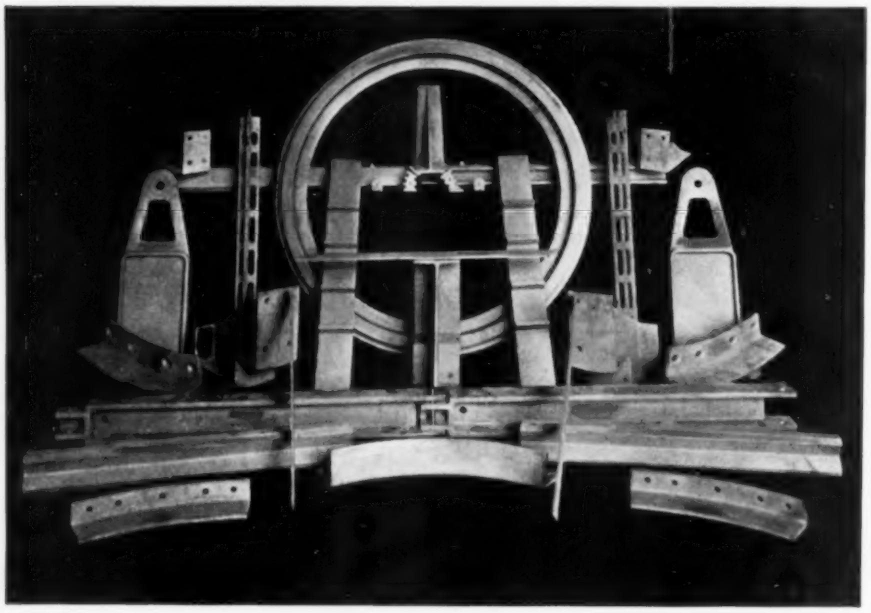
Wesley H. Millard has left the Friend Mfg. Co. to join the Metallurgy Department of Pratt & Whitney Division, Niles Bement Pond Corp.

Harry L. Myers has been promoted to the position of general superintendent of the West Leechburg Division, Allegheny Steel Co.

W. Gerhardt Leaman is now assistant metallographist in the new strip mill at the Lackawanna plant of Bethlehem Steel Co.

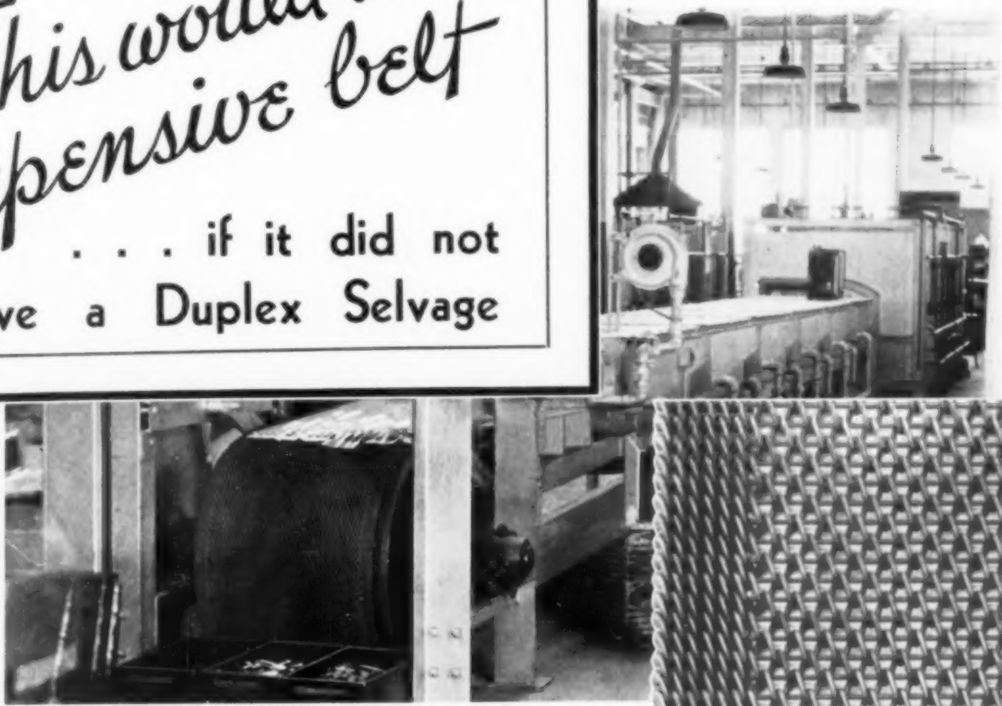
Edwin H. Engel has been transferred from the metallurgical department, Sheet and Strip Division, Pittsburgh District, to the Vandergrift Works, Carnegie-Illinois Steel Corp., where he is assistant metallurgist.

Nathan Lester, formerly associated with the Superior Die Casting Co., has opened an office of his own as the Lester Engineering Co. in Cleveland.

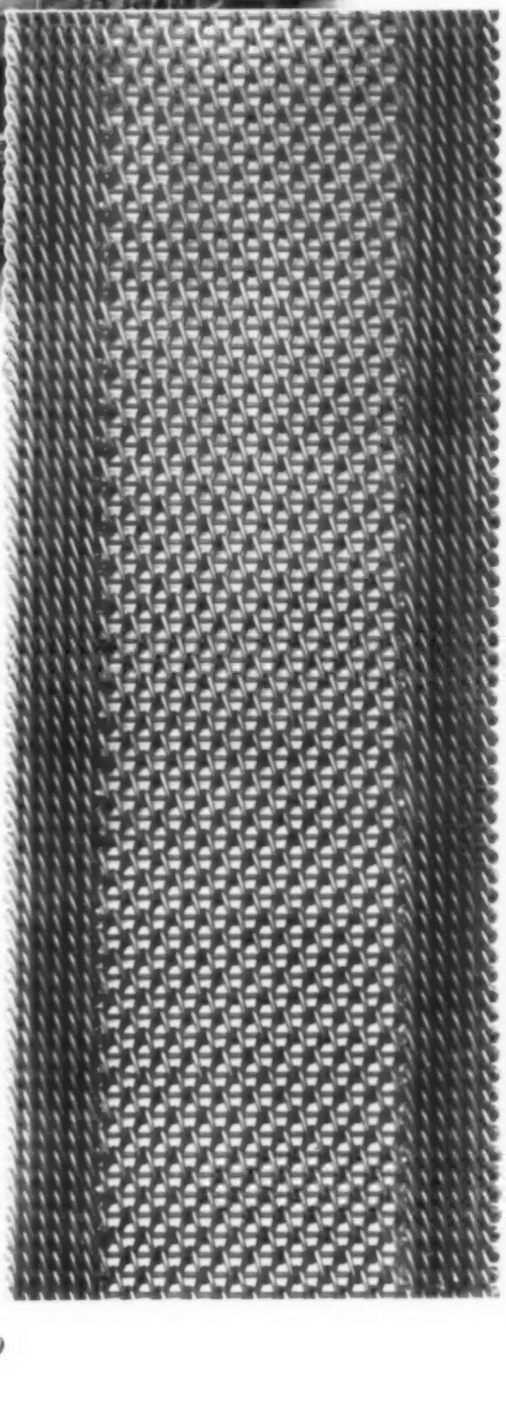


This would be an expensive belt

. . . if it did not have a Duplex Selvage



One of three Surface Combustion Corporation furnaces at Oneida, Ltd., Oneida, N. Y. equipped by Surface Combustion Corp. with Cambridge Duplex Selvage Woven Wire Belts.



Duplex Selvage is added strength where strains are greatest. A Cambridge Spiral Woven Wire Conveyor Belt with selvages reinforced with a true double weave — identical in every respect with the weave of the belt fabric itself — unaltered uniformity of belt structure — unimpaired flexibility — unchanged belt surface smoothness — results in operating freedom from edge wear and tear and consequent belt disruption.

There is also a hidden virtue in the Cambridge Duplex Selvage which is brought to light under elevated temperature belt applications. Here Duplex Selvage has proven to be more than merely belt edge protection, but an area within which the ever-present belt operating stresses are absorbed and arrested from developing further into the inner belt fabric as destructive belt strains, the cause of belt distortion, stretch and width contraction.

The
Cambridge Wire Cloth Co.
Cambridge - Maryland

Boston — New York — Baltimore — Detroit — Chicago — San Francisco

MAGNESIUM ALLOYS FOR AIRCRAFT

By Cecil H. Desch

Abstract of paper for Royal Aeronautical Society, Meeting of Jan. 14, 1937

Magnesium is too weak a metal to be used in the unalloyed state, yet the metals which may be added to it to produce strong alloys are very limited in number. Solid solution alloys are necessary for any considerable strengthening, and Hume-Rothery's survey of known alloy systems shows that the atom diameters of the metals must be within 14% of each other for appreciable solution. It is not surprising, therefore, that beryllium is hopeless for this purpose. Even though both metals belong to the same group in the periodic system, both are light metals and both crystallize in the same system; the magnesium atom with effective atomic diameter of 3.20 Å is so much larger than beryllium (2.25 Å) that *molten* magnesium will not even dissolve beryllium.

When the 14% rule is used to direct researches into strengthening alloys for magnesium, it is found that the following metals fall within the limits: Lithium, aluminum, zirconium, thallium, lead, and bismuth. Several of these, however, including tin, antimony, thallium, lead, and bismuth, form compounds with magnesium which are both brittle and reactive, and when all the factors are taken into account, we are left with only aluminum and cadmium as suitable for alloying in more than quite small quantities. On the other hand, calcium, cerium, zinc, nickel, cobalt and manganese, which fall outside the 14% limit, and can only form solid solutions to a very limited extent, have proved useful in small quantities.

It is well known that various combinations of aluminum, manganese and zinc are used with strong magnesium alloys, both cast and wrought. Of the remaining possibilities cadmium and silver seemed most promising, and experiments were therefore made at the National Physical Laboratory to test the effect of adding small quantities of silver to alloys having already good properties. It may be mentioned in passing that the fact that the added metal is relatively costly is of little importance. In the production of many objects, the cost of manufacture is so much greater than that of the material that an addition to the cost

of the alloy is hardly appreciable in the product.

The simple binary alloys with metals other than aluminum do not, so far, offer great advantages. Cadmium alloys readily with magnesium, the tensile strength being little changed, even by large additions, and the alloys are very ductile, the elongation increasing to 20% in 2 in. with cadmium up to 15%, and this property is retained in the ternary alloys with zinc. Rolled strip containing 4% Cd and 4% Zn gave a tensile strength of 38,500 psi. and an elongation of 22%. This strip could be spun cold into simple forms if given several intermediate annealings. Higher strengths, along with somewhat lower ductility, were obtained from alloys containing cadmium together with aluminum.

For highly stressed parts it is necessary to raise the proof stress as well as the tensile strength, and for this purpose some form of age hardening would seem to be desirable. Silver was found to be useful in this respect, and patent applications have been filed. For example, an alloy with 8% Al, 8% Cd, 2% Ag in 1-in. forged bars, after heat treatment, tested 64,000 psi. ultimate tensile strength, 44,000 psi. proof stress at 0.1% elongation, 4.2% elongation. The heat treatment consisted of 2 hr. at 775° F., a quench, and aging 6 days at 265° F. Adding 2.5 to 3.0% silver to magnesium alloys containing about 8% Al, 0.4% Mn and 0.2% Ca gives tensile strengths of 56,500 psi., proof stresses of 37,000 psi., and elongations of 3.5 to 4.0%. Adding 0.7% zinc to the last mentioned alloys will increase the elongation to 6.0%.

The following figures have been obtained from propeller blades forged in the press (the alloy being slightly modified) without age hardening, but with careful control of the crystal structure during the forging operations: Tensile strength, 45,000 to 51,500 psi.; 0.1% proof stress, 27,000 to 31,500 psi.; elongation, 5 to 11%; Wöhler fatigue range, ±16,800 to ±19,000 psi.

The strength of magnesium alloys falls off rapidly with increasing temperature, but the rate of fall varies greatly with the composition, so that a choice of alloys has to be made. For aircraft purposes, two ranges of temperature have to be considered. For crankcases a maximum of 300° F. may be taken, while for pistons a much higher temperature, 650° C. or more, has to be considered. Since these operating temperatures are above the usual aging temperature, the problem of finding suitable alloys resolves itself into that of discovering structures of inherent strength at high temperatures, stable under prolonged heating or repeated intermittent heating and cooling. This does not necessarily mean using homogeneous solid solutions, as a network structure may be present, provided it is not one that is absorbed and reprecipitated within the working range of temperature.

(*Continued on page 302*)

MAGNESIUM ALLOYS

(*Starts on page 300*)

The required properties cannot be determined by simple tensile tests at high temperatures; creep becomes important when the stress is continued for a long time. Few of the alloys have been tested under rigorous creep conditions, and the data available have been mostly obtained from accelerated tests. For the alloys containing aluminum, however, some general conclusions may be given; as with other metals, cast alloys have better creep resistance than forged.

In the course of tests at the National Physical Laboratories, aluminum, silver, manganese, calcium, nickel and cerium were found to strengthen magnesium, the strength-temperature curves being raised throughout their course, while combinations of two metals have a rather greater effect than one alone. Calcium is a useful addition for this purpose; it is actually lighter than magnesium and also improves the casting properties in so small a quantity as 0.35%. Cerium, on the order of 1%, has a marked strengthening effect at 575° F., while when nickel is also added the hardness is similar to that of Y-alloy in the same range of temperature. Nickel, however, has some disadvantages and cobalt has given better results. The following tests were obtained from forged alloy containing 10% cerium, 1.5% cobalt and 1.5% manganese:

Temperature °C.	Temperature °F.	Tensile Strength	Elongation
20	70	41,700	0
100	212	34,000	2.4
200	390	29,500	2.0
300	575	16,600	152.0

Cadmium, lithium, thallium, lead, zinc, tin, copper, and silicon were found ineffective as means of improving the properties at high temperatures.

It is particularly in the neighborhood of 300° F. that information as to the behavior in creep is required, on account of the application to crankcases. The suitability of the alloys for pistons at higher temperature is determined by a combination of qualities, of which resistance to creep is not the most important, such as permanence of dimensions, resistance to fatigue, stability of internal structure (absence of changes leading to increased brittleness), thermal conductivity. Pistons made of alloys similar to those mentioned have given excellent results in trial runs under overload, and it is probable that improvements in composition are the best means of obtaining better performance.

An obvious difficulty in the use of alloys of magnesium is their ready corrodibility. Magnesium is a highly reactive metal; no addition of an alloying metal, in quantities (*Continued on page 304*)

MAGNESIUM ALLOYS

(*Starts on page 300*) within the range of the light alloys, will inhibit this corrosion, although the influence of small quantities of manganese is known to be favorable. Actually, however, the resistance is greater than might have been expected. A simple film formed by exposure to air affords some protection, so that a specimen left in the open in a fairly clean atmosphere will only show a thin white crust when a piece of iron exposed at the same time is thick with rust. The fact that iron rusts easily does not prevent its use, and both metals must be protected by some kind of coating against atmospheric attack. Chemical treatment [such as noted in the editorial review in January **Metal Progress**] is relied upon, not only to protect by itself against atmospheric attack but to serve as a basis to retain a coating of varnish, paint, or enamel.

Much study has been given to the attack of leaded gasoline on sheet magnesium tanks. Some organic substances inhibit the attack without impairing the anti-knock qualities, notably quinoline when added to the extent of 1%.

Chlorides accelerate the corrosion of magnesium and its alloys, and tend to break down any protective film on the surface. An inert varnish of some kind is then essential, as well as the chemically prepared coating. Since the flux used in casting or welding usually contains chlorides, it is of utmost importance that the metal contain the minimum of inclusions and the surface be carefully cleaned. Scrubbing with hot water containing 15% potassium dichromate will serve when electrolytic cleaning is impracticable.

The protection of the surface of airscrews presents a specially difficult problem. Here it is not so much a question of chemical corrosion, as rather of abrasion of the leading edge by dust particles and rain drops, in consequence of the high velocity. Even the very adherent coating produced by the chromate treatment suffers under these abrasive conditions, and paints and enamels prove inadequate. Treatment with chromate, followed by lanoline or a varnish with a base of Tung oil, affords as much protection as can be expected, but there is room for improvement in this direction. The ideal surface to resist such severe abrasion would be a hard metallic coating, preferably of chromium, and this is the direction in which success is likely to be found. To deposit chromium directly on a magnesium alloy is almost certainly impracticable, but the production of intermediate metallic coatings, free from pinholes and capable of receiving an electrolytic deposit of chromium, seems to be promising.

METAL SPRAYING

By E. C. Rollason

Abstract from Paper No. 760
Institute of Metals, 1937 Spring Meeting
(Advance Copy)

IN RECENT YEARS new designs of spraying apparatus have been evolved using wire, powder, and molten metal. Many new applications have also been exploited successfully, some of which are becoming of great importance to the engineer. Apart from these, metal spraying demands increasing consideration as a means of combating corrosion of mild steel, since the austenitic "stainless" steels are too expensive for any but special environments where corrosion is very severe. The most common method of protecting iron and steel is by painting, but this is only really effective when the surface is prepared or cleaned by costly treatments such as sandblasting. This is the first stage in the metal spraying process, and, if one is prepared to do this, a coat of sprayed zinc or aluminum makes the ideal protective coating for steel, whether or not subsequent coats of paint are sprayed onto the deposit.

Three principal types of pistols are now available; one uses wire, another molten metal, the third metallic powder.

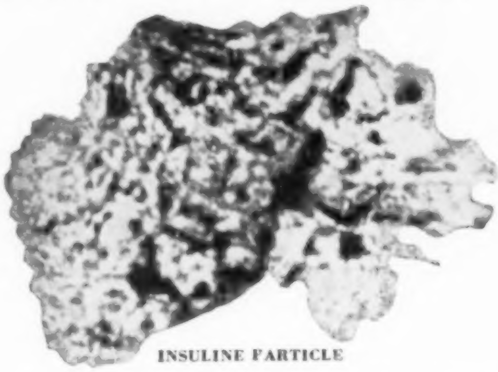
All pistols spraying metal from wire differ only in details of design. They contain a small air turbine which drives two knurled rolls which feed the wire into the melting nozzle. Compressed city gas or acetylene and oxygen are supplied for the flame, while compressed air is used for atomizing the molten metal. Its speed of application is smallest, normally 5 lb. of metal per hr. This can be more than doubled by increasing the wire size to 2 mm. (12 gage). One of the important advantages of the wire pistol over other forms is the ease with which the internal surfaces of tubes can be coated. For tubes as small as 1.25 in. the rotary nozzle is used, while for larger tubes either the extension or the deflector nozzles are suitable.

Recent modifications of pistols using molten metal have reduced their size and weight to about double that of a wire pistol. It is gravity fed with molten metal held in a container (carrying about 4 lb. of zinc) and its temperature is maintained by a gas flame, which also preheats the compressed air, carried by a stainless steel pipe to the silver steel nozzle. One of the *(Continued on page 308)*

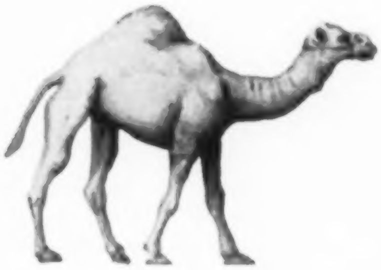
INSULINE

(REG. U. S. PAT. OFF. PATENTS PENDING)

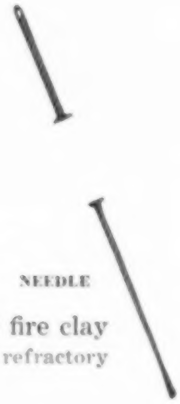
CAN but the camel CAN'T pass through the needle's eye



INSULINE PARTICLE



CAMEL



NEEDLE

Pictured above is an INSULINE Particle magnified 2100 times. Its stable, calcined fire clay base——with thin-walled, minute, cellular structure——produces the light weight, low heat storage, refractory and insulating properties of INSULINE Products described below.

INSULBRIX

(REG. U. S. PAT. OFF.)

INSULBRIX are light-weight cellular low heat storage insulating fire brick for direct or indirect exposure to flame and furnace gases in boiler and other furnaces, ovens, and kilns.

INSULBRIX are made in several brands from one-tenth to one-seventeenth the heat storage capacity of heavy refractories; 1" has an insulating value of 3" to 5" of fire brick; permit heated equipment to: reach operating conditions in less time; meet fluctuations more rapidly.

Result in: increased output; conservation of fuel; decreased labor costs; improved furnace room conditions; greater comfort to the workmen.

INSULCRETE

(REG. U. S. PAT. OFF.)

INSULCRETE is a light-weight cellular insulating refractory concrete for furnace linings, door linings, heat shields, shapes, covers, and kindred uses; recommended for temperatures up to 2500°F. No cutting, fitting or ramming—**just pour into place.**

1" of INSULCRETE equals about 4" of fire brick in insulating value and has about one-seventh the heat storage capacity of fire brick walls of equal heat flow.

INSULAG

(REG. U. S. PAT. OFF.)

INSULAG is a superior plastic refractory lagging and finishing insulating material for high temperature equipment up to 2200°F. It is also used to fireproof bins, walls, wood columns, roof structures, etc. INSULAG does not shrink—expands as it dries, sets quickly and bonds firmly to hot or cold surfaces. Has high crushing strength and does not bruise or break in ordinary service.

Does not dissolve or collapse from contact with water, and is practically inert to vapors of steam, oil, acid or alkaline solutions.

It is quickly and easily applied by molding, troweling or Quigley Refractory Gun wherever plastic insulation is required. 1" of INSULAG has an insulating value equal to about 9" of fire brick and has about one-fortieth the heat storage capacity of fire brick walls of equal heat flow.

INSULBLOX

(REG. U. S. PAT. OFF.)

INSULBLOX are superior refractory block insulation used for direct exposure up to 2000°F. and for indirect at 2200°F. They permit the use of insulation closer to the fire. INSULBLOX, because of their calcined stable fire clay base stand severe service. Do not lose their insulating properties nor shrink from the brickwork where properly used.

INSULBLOX do not **dissolve or collapse from contact with water** and are resistant to vapors of steam, oil, acid or alkaline solutions.

INSULBLOX are made in standard thicknesses—1" to 6". Pick your thickness and avoid waste. Large-size units reduce installation costs and joint losses.

The heat storage capacity of INSULBLOX is about one-fortieth that of fire brick for the same heat flow. 1" thickness of INSULBLOX is equal in insulating properties to about 9" of fire brick.

INSULINE — Ground **INSULINE** — Sized Aggregate

INSULINE is available in Ground form for use as insulating fill and as Sized Aggregate for use with Portland Cement or other suitable binders to make an insulating concrete.

For further information write for copy of "APPEAL TO REASON"

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Makers of **HYTEMPITE**, *"The World's Standard High Temperature Cement"*

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METAL SPRAYING

(*Starts on page 306*) difficulties is that the silver steel nozzle and also the container is rapidly attacked by the molten zinc; the former has a life of 1 to $1\frac{1}{2}$ hr., renewable in 2 to 3 min. This process also requires a separate furnace for melting the zinc. This pistol, as well as the one now to be described, has no moving parts.

Of the powder pistols invented, only the Schori has become of commercial importance. The powder is sucked through an oxy-gas flame and blown onto the object. The construction consists essentially of two injector arrangements; one is in the handle and is similar to that found in a welding blowpipe, while the other, similar to a filter pump, is used for aspirating the powder from a suitable container fitted with a small vibration fan. Two difficulties are met with in the design of equipment for spraying metal powders: A large orifice in the nozzle is required to prevent clogging by the powder, and a large flame is also required. The second is the maintenance of a regular supply of powder to the pistol. However, the pistol itself is lightest in weight (about $2\frac{3}{4}$ lb.) and the speed of application is highest.

Normal working distance is 3 in. for the wire nozzle, 5 in. for the molten metal nozzle, and 10 to 12 in. for the powder nozzle; overhead work is, of course, impossible with the molten metal nozzle.

Common applications at present are:

Zinc coatings afford excellent protection for iron and steel, and are particularly useful for steel windows, light-gage sheet metal, springs, and non-metallic articles; they are excellent bases for paint.

Aluminum coatings are resistant to sulphurous atmospheres, and the very pure metal is gaining favor as a coating for the steel parts of aircraft. Aluminizing is also used to prevent scaling in equipment operating up to 1750° F.

Tin is used principally for food vessels.

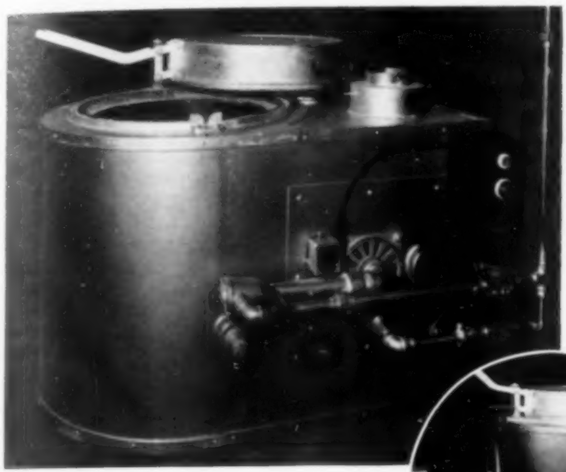
Lead, nickel, copper, steel, and **stainless** steel coatings all have their uses, the harder metals particularly for building up worn machine parts and blowholes in castings where only compressive strength is required.

Among the more novel applications may be mentioned the treatment of insulators, radio apparatus, diathermic bandages, and wall paper.

It appears that each of the three types of metal-spray equipment has characteristic advantages which will allow all of them to survive competition and become useful tools in the engineers' hands.

(*Continued on page 314*)

1200° IN 21 MINUTES!



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If you're interested in economy, you'll want to know more about this latest Despatch achievement. It's an interesting departure from the conventional tempering and drawing furnaces of today.

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HELPFUL LITERATURE

Stress-Strain Recorder

The many applications of the Baldwin-Southwark stress-strain recorder, its unique advantages, and the many ways it can give unusual service will be extremely interesting to all who have to do with testing methods and equipment. Bulletin Ba-67.

Electrodes

Recommended welding procedures for the new "Shield-Arc 100" electrode as well as all other Lincoln electrodes are contained in the latest "Supplies Bulletin" published by Lincoln Electric Co. Bulletin Ba-10.

Stabilog

Ten outstanding advantages of the potentiometer Stabilog are fully explained in an attractively laid-out folder by the Foxboro Co. Bulletin Ba-21.

Cleaning Processes

An attractive 12-page booklet entitled "Scientific Metal Cleaning" has been published by Detroit Rex Products Co. It describes in detail the applications and advantages of Detrex degreasing with Perm-A-Clor or Triad Safety Solvents and the applications of Triad Alkali Cleaning Compounds and Strippers. Bulletin Oy-111.

Oil Testing

An oil testing instrument catalog issued by C. J. Tagliabue Mfg. Co. should be in the hands of every oil chemist as well as all those who are interested in testing machines. An up-to-date price list is included. Bulletin Ba-62.

Hard Case

A continuous breakdown test on Holden Hard Case heat treating bath is fully described and the remarkable results explained in a folder by A. F. Holden Co. Bulletin Ba-55.

Modern Metallograph

The new Bausch & Lomb research metallographic equipment, which is arousing so much interest and favorable comment in the profession, is the subject of advance literature, recently issued. Bulletin Ba-35.

Oxygen Lance

An eight-page booklet, profusely illustrated with diagrams and pictures, puts into convenient form much valuable information on the oxygen lance, which will be especially useful to anyone working with heavy sections of metal. The Linde Air Products Co. Bulletin Ba-63.

Nickel Silver

Riverside Metal Co. has just published a beautiful booklet on nickel silver. If you want the latest information on this subject, presented in an attractive, interesting manner, write for Bulletin Aa-156.

Sicromo

Timken Steel & Tube Co. has issued a new booklet on Sicromo steels which gives analyses of these new steels and discusses the effect of both silicon and chromium on oxidation resistance. Bulletin Ba-71.

Laboratory Service

A new edition of "The Metal Analyist" tells about an organization established by Adolph I. Buehler specializing in the installation of metallurgical laboratories. The complete line of laboratory equipment marketed by Buehler is also catalogued. Bulletin Dy-135.

Testing Machines

An extremely handsome, spiral-bound, segregated catalog tells all about the various hydraulic and screw power testing machines made by Tinius Olsen Testing Machine Co. Bulletin Oy-147.

Nickel-Copper Steels

Exceptional resistance to corrosion and abrasion, increased tensile strength, and higher ductility are the qualities claimed for Youngstown Sheet & Tube Co.'s new series of Yoloy steels. A summary of properties and notes on their characteristics are contained in Bulletin Ox-93.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

Electric Salt Baths

Literature is available from Bellis Heat Treating Co. describing electrically heated bath furnaces which are economical to operate and have a wide range of applications in hardening, annealing, and heat treatment of high speed steel, stainless steel, nickel, aluminum, copper and bronze, etc. Bulletin Ny-48.

Heat Treating Manual

A folder of Chicago Flexible Shaft Co. contains conveniently arranged information on heat treating equipment for schools, laboratories and shops, and also illustrates the several types of Stewart industrial furnaces. Bulletin Ar-49.

Newer Tool Steels

Vulcan Crucible Steel Co. has a complete and attractive catalog listing their full line of tool steels including many special types to meet the modern trends in industry. Bulletin Jyb-127.

Testing with Monotron

Shore Instrument & Mfg. Co. offers a new bulletin on Monotron hardness testing machines which function quickly and accurately under all conditions of practice. Bulletin Je-33.

Corrugated Ingots

The Gathmann Engineering Co. has published a new booklet called "Gathmann Ingot Molds — Their Purpose and Design." It illustrates various corrugated ingot contours designed to produce defect-free surface in steel ingots. Bulletin Aya-13.

Metal Surfaces

A manual giving in detail methods for the application of sodium cyanide solutions in the preparation of metal surfaces is announced by the R. & H. Chemicals Department, E. I. du Pont de Nemours & Co. Bulletin Ba-29.

Brinell Tester

Accurate and exact measurements can be made on hard or soft materials with the Diamo-Brinell hardness testing machine, which uses a pyramid-shaped diamond instead of a steel ball. Described in a pamphlet by Pittsburgh Instrument and Machine Co. Bulletin Aa-1.

EPI Microscope

The Zeiss EPI microscope for the illumination and observation of opaque material has unlimited applications for observing opaque material in dark field, bright field, and polarized light. A descriptive leaflet is published by Carl Zeiss, Inc. Bulletin Aa-28.

Ni-Cr Castings

Compositions, properties, and uses of the high nickel-chromium castings made by The Electro Alloys Co. for heat, corrosion and abrasion resistance are concisely stated in a handy illustrated booklet. Bulletin Fx-32.

Compressor Data

General information on the application of blowers to gas and oil burners, and miscellaneous applications for other types of work are included in a 12-page "Turbo Compressor Data Book." Useful tables and charts are included. Spencer Turbine Co. Bulletin Dy-70.

Ovens

Maehler recirculating ovens speed baking and reduce fuel costs. Why is told in a well-printed and illustrated booklet by The Paul Maehler Co. Bulletin Ba-159.

Port Valves

Diagrams and descriptive matter show the operation of adjustable port valves made by North American Mfg. Co. that are particularly suitable for mediums whose rate of flow is not constant. Bulletin Oy-138.

Moly Matrix

Climax Molybdenum Co.'s little monthly newspaper contains many interesting and informative articles. Get the latest issue — Bulletin Ax-4.

Pot Furnaces

The new features of American Gas Furnace Co.'s improved pot hardening furnaces include insulating refractory lining backed by block insulation, heat resisting alloy burners, single valve control, numerous small burners with their attendant advantages, burner location and method of venting. Fully described in Bulletin Sy-11.

Profile Projectors

A piece of equipment designed to meet the ever-increasing demand for optical measuring instruments of the highest precision is the Leitz profile (contour) projector. Its many new construction features are illustrated and described in a 28 page pamphlet. Bulletin Aya-47.

Metal Working

Concise but informative is a little booklet by E. F. Houghton & Co. describing various metal-working products — rust preventives, cutting oils, metal cleaners, quenching oils, carburizers, pickling inhibitors, and miscellaneous products. Bulletin Co-38.

Cast Vanadium Steel

Jerome Strauss and George L. Norris have written a technical booklet for Vanadium Corp. of America describing the properties developed by steel castings containing various percentages of vanadium. The information given is complete and authoritative. Bulletin S-27.

Monel for Strength

A publication by International Nickel Co. presents briefly, yet in an interesting and striking manner, the story of this nickel-copper alloy whose combination of mechanical properties with resistance to chemical corrosion has answered many problems of industry. Bulletin Co-45.

Some of the Best Thinking

in the metal industries is at your disposal in the literature described here. One booklet may hold the key to your current problem. Help yourself to this helpful literature. It's free. You incur no obligation when you return the coupon.

Burner Economy

Interesting photographs and text are used by Surface Combustion Corp. to show that a choice of 47 different types and more than 400 different sizes is sure to give economy in operation. Bulletin Ca-51.

Conveyor Furnaces

Continuous chain belt conveyor furnaces handle miscellaneous parts without pans or trays — they are efficient, uniform, and flexible in operation. Improved furnaces of this type are described by Electric Furnace Co. Bulletin Ayx-30.

Micromax Model

A novel publication by Leeds & Northrup Co. has the effect of almost putting a half-size model of the Silver Anniversary Micromax recorder in your hands. Cut to the actual shape of the recorder, it can be opened out and the whole mechanism swung into place. Bulletin Ca-46.

Resistance Wire

A complete catalog of the various types of electric resistance wires made by Hoskins Mfg. Co. has been issued. Complete numerical data are included on all types, along with some fundamental facts about heating units. A handy, small size 48-page booklet. Bulletin Jyb-24.

Centrifugal Castings

Centrifugal casting of stainless, heat and corrosion resisting alloys eliminates impurities and cooling strains and permits thinner and more uniform walls than any other method. This is explained in a bulletin by Michigan Steel Casting Co. Bulletin Nx-84.

Cleaning Rooms

A catalog of designs for blast cleaning rooms incorporating many labor and time saving improvements making the blast room an unequalled mechanical device for low cost cleaning is published by Pangborn Corporation. Bulletin Ca-68.

Thermit Welding

Of interest to all who are concerned with welding, but of particular interest to students is a pamphlet of carefully explained and illustrated laboratory experiments in thermit welding published by Metal & Thermit Corp. Bulletin Ca-64.

Inert Gas

The rapid development in the use of inert gases in industry during recent years makes a folder of Roots-Connersville Blower Corp. particularly timely. It describes the Harrison inert gas producer — a fairly new but well-proven piece of equipment. Bulletin Ca-131.

Bessemer Steel

Jones & Laughlin Steel Corp. has for distribution reprints of the paper by C. C. Henning on "Manufacture and Properties of Bessemer Steel" that received the Robert W. Hunt Award of the A.I.M.E. during 1935. Bulletin Ca-50.

Nichrome Containers

The important part that containers play in economical and dependable carburizing is well known to metallurgists and heat treaters. A Driver-Harris Co. bulletin on Nichrome carburizing containers should therefore not be neglected. Bulletin Ca-19.

Cold Finished Bars

The importance of quality in cold finished steel bars is stressed in a small booklet by Union Drawn Steel Co., which describes the various types of carbon and alloy steels available in this form. Bulletin Ca-83.

Photo-Electric Cells

If you are not familiar with the wide field of applications for photo-electric cells and apparatus, send for this very interesting and complete booklet by Pfaltz & Bauer, Inc. covering the original apparatus developed by Dr. Bruno Lange. Bulletin Ca-142.

Die Blocks

A handy, small size spiral-bound leather notebook is a complete handbook on Heppenstall Company's die blocks. Valuable additional data are contained, as well as a few blank pages for memoranda. Bulletin Ca-122.

Pickling Inhibitors

A pamphlet describing the nature and use of Grasselli Inhibitors is offered to those interested in pickling steel. It not only describes the merits of these inhibitors, but also gives a table of inhibitor strengths for use in pickling various steels. Bulletin Ap-95.

Gas-Fired Cyclone

Lindberg Steel Treating Co. has announced a gas-fired Cyclone furnace as a companion to the electric Cyclone. Complete data in the form of diagrams, charts, photographs, and blueprints are found in a new catalog. Bulletin Jya-66.

Radio Principle

How a tried and accepted principle of radio engineering is successfully applied to industrial control instrumentation is described in a folder on a new low-price automatic controller by Wheelco Instruments Co. Bulletin Ca-110.

Silver Solder

Characteristics and uses of 12 standard compositions of silver solders meeting almost all requirements for this useful material are described in a folder by Handy & Harman, Inc. Bulletin Aa-126.

Inductive Heating

A reprint from *General Electric Review*, technical house organ of General Electric Co., is a detailed exposition of inductive heating by N. R. Stansel, industrial engineer for G. E. Bulletin Ca-60.

Castable Refractory

Properties, method of use, and applications of "Cast-Refract," a time and labor-saving castable refractory made by the Quigley Co., are given in Bulletin Oy-139.

Spoilage Fear

Fear of spoilage, says C. I. Hayes, Inc., may cost a firm more than actual tool loss through spoilage in the furnace. How "certain curtain" furnaces eliminate spoilage and spoilage fear is told in Bulletin Aa-15.

Grinding Lubrication

A handy outline for the selection of grinding wheels is one of the useful features of a booklet full of facts about grinding solutions. D. A. Stuart & Co. Bulletin Mya-118.

Salt Bath

"Heating from the inside out" is what makes the Ajax-Hultgren salt bath furnace practical. Ajax Electric Co. explains this new operating principle in an interesting folder. Bulletin Oy-43.

Rockwell Tester

A revised and completely up-to-date catalog on the well-known Rockwell hardness tester is well illustrated and contains 24 pages. Published by Wilson Mechanical Instrument Co., Inc. Bulletin Ca-22.

Ovens for Finishing

Despatch Oven Co. has two new bulletins featuring ovens for various finishing processes on such things as steel barrels, bed springs, cabinets, stoves and steel doors. Bulletin Oy-123.

Abrasion Resisting

Striking indeed is the yellow covered publication by Carnegie-Illinois Steel Corp. giving the history of AR steel, a low-priced abrasion resisting steel, and showing actual results in service as compared to ordinary mild steel. Bulletin Mya-85.

Diamond Wheels

A striking presentation is made by the Carborundum Co. in a 52-page booklet on diamond wheels. Detailed technical information is contained and a price list attached. Bulletin Ca-57.

Dust Collector

How the Schneible multi-wash dust and fume collector operates and what it does are clearly shown in a catalog giving details on existing installations. Published by Claude B. Schneible Co. Bulletin Ca-161.

4 to 6% Cr

Fifth of the series of beautifully printed booklets describing Republic Steel Corp.'s Enduro types is concerned with the 4 to 6% chromium steel. Its particular application to oil refining is described in detail. Bulletin Ca-8.

Pot Furnaces

Hevi Duty Electric Co.'s line of pot type furnaces for immersion heat treating; lead and salt bath treatment; melting and heating babbitt, lead, and solder; and for tinning and galvanizing is described in Bulletin Ayx-44.

Alcoa Notes

"Alcoa Random Notes" is the intriguing title of a little monthly paper got out by Aluminum Co. of America. A request for this bulletin will bring you a copy of the latest issue. Bulletin Ca-54.

Optimatic System

The Brown Optimatic System is a self-balancing automatic optical pyrometer which records temperature readings with the speed of light — the human eye is eliminated. It is described by Brown Instrument Co. in Bulletin Ny-3.

Metal Progress,
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Ba-21	Dy-135	Aya-13	Ax-4	Ca-46	Ca-83	Oy-139	Ca-161
Oy-111	Oy-147	Ba-29	Sy-11	Jyb-24	Ca-142	Aa-15	Ca-8
Ba-62	Ox-93	Aa-1	Aya-47	Nx-84	Ca-122	Mya-118	Ayx-44
Ba-55	D-17	Aa-28	Ca-38	Ca-68	Ap-95	Oy-43	Ca-54
Ba-35	Ny-48	Fx-82	S-27	Ca-64	Jya-66	Ca-22	Ny-3
Ba-63	Ar-49	Dy-70	Ca-45	Ca-131	Ca-110	Oy-123	

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† Deceased.

METAL SPRAYING

(*Starts on page 306*)

Owing to its low costs, the powder process will undoubtedly prove successful in spraying large surfaces with zinc, especially when the coat is subsequently painted. This powder-pistol also offers possibilities of spraying brittle metals which cannot be drawn into wire. Deposits of the higher melting point metals which have been examined are not wholly satisfactory.

The molten metal instrument can produce thick coatings of the low melting point metals at a reasonable price, and should prove useful to the galvanizer doing contract work, especially as ingot metal is used and neither acetylene nor oxygen is required.

The wire pistol, on the other hand, will without doubt hold the field in building up thick deposits on worn articles and also for producing heat resisting surfaces. Even in the production of high cost zinc coating, the wire pistol offers advantages in the internal spraying of work.

The hypothesis favored by the present author concerning the mechanism of the metalizing process is that the particles are melted completely or partially in the flame, and cool fairly slowly while traveling in the air stream, since there is little differential movement of the two materials. When the pistol is held close to the article (1 to 3 in.), the particles are still molten when they strike the surface. Splashes like fallen drops of solder are formed and interlock together. At high magnifications the microstructures of these splashes exhibit columnar crystallization, with discontinuous oxide films and cavities at the edges of the lamination; these crystals must have formed after the particles had struck the surface. After deposition, the particles are rapidly cooled by the air stream impinging against the surface, and since the base only conducts away a small proportion of the heat, a flammable material may not be ignited. At greater distances from the nozzle the particles will be cooled below their freezing point, splashes will not form, but with sufficient kinetic energy the particles will be deformed into a laminated packing enclosing fine pores. At still greater distances the particles form a "heaped" sand-like mass with high porosity.

One important difference between the deposits produced by wire and by powder is that the latter does not give as much "splash effect" with metals of high melting point (such as copper). In all cases the grain size, as shown by X-rays, is very small.

A number of corrosion tests were made on samples of ingot iron of known history metallized in various ways and then exposed to the tests of the Iron and Steel Institute's (*Continued on page 316*)

METAL SPRAYING

(*Starts on page 306*) Corrosion Committee. As yet the field tests have not progressed long enough to yield reliable results. The general trend of the other tests is that the sample sprayed at normal distances from the nozzle offer a greater resistance to corrosion than those sprayed either near or far from the nozzle.

All the zinc coatings made under good commercial practice have approximately the same rate of corrosion, and this life is limited mainly by the thickness of the deposit. That the life will be satisfactory is also shown by salt spray tests; samples metallized by each of the processes withstood 1000 hr. without signs of rusting.

The aluminum-coated specimens, however, showed widely different characteristics. In the accelerated tests the sample sprayed by the powder process exhibited rust spots within 26 days, the surface became gray and hygroscopic, while in the field tests rust appeared within seven months. The sample sprayed with aluminum-silicon alloy by the molten metal process was soon covered with a white deposit, and at the end of 70 days' exposure to the salt spray the coating was blistered and could be removed readily as powder. On the other hand, the wire process yielded a specimen which remained unaffected and bright up to 170 days, after which period a few rust spots appeared.

In order to test the resistance to oxidation, aluminum wire, aluminum powder and molten aluminum-silicon alloy were sprayed on mild steel. These were then heated to permit the aluminum to diffuse into the steel surface, first having painted the sample with a coating designed to protect the aluminum while this diffusion layer is forming. These different treatments, patented in the respective countries are:

English: Coat specimen with bitumastic paint, heat rapidly to 1450° F. for 10 min.

German: Coat specimens with water glass, heat rapidly to 1475° F. for 15 min.

French: Coat with saturated solution of borax and anneal at 1100° F. for 30 min.

After treatment, the samples were heated for 5-hr. periods at 1700° F. in a muffle, after which they were quenched in water; this has a very drastic effect on any surface scale. For comparison, samples of mild steel, 6% silicon cast iron, and 18-8 chromium-nickel steel were included, together with steel specimens spray coated with 18-8 wire and with nichrome wire. The two latter specimens were previously annealed at 2000° F. for 2 hr. without protection in order to form a diffused layer.

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METAL SPRAYING

(*Starts on page 306*)

The bitumastic paint protection appears to be very successful, and the wire process yields the best results. Even after 250 hr. under test the specimen coated with nickel-chromium-iron showed a negligible change in weight. Time for comparable weight loss in the other samples is as follows:

18-8 plate	300
Aluminum wire spray, English or German treatment	150
Cadmium-aluminum wire spray, no pre-treatment	130
Silicon cast iron	100
Aluminum powder, English or German treatment	85
Molten aluminum-silicon alloy, English treatment	85
18-8 wire spray	50
Bare mild steel	7

The density of sprayed metal is always less than that of cast material, and this is due partly to porosity and partly to oxide particles. The porosity consists of isolated cavities and interconnected pores; both types of porosity were measured for coatings made in a large number of ways by stripping a built-up layer, boiling in toluene, and weighing when suspended in toluene. The toluene penetrates the pores with great rapidity, and the specific gravity subsequently calculated is that of the metal, oxide, and isolated pores. After the toluene was driven off the specimens were next coated with a very thin film of vaseline and weighed suspended in distilled water. The film of grease prevented the water from penetrating the pores; the difference between the two calculated specific gravities indicates the extent of isolated pores together with oxides.

Results show that the powder process produces deposits with the greatest porosity, and this is undoubtedly due to the fact that the particles are cooler when they strike. A wire pistol, using city gas, produced zinc deposits with low interconnected porosity, but the low density (in toluene) clearly indicates that there is an appreciable number of isolated pores. This is confirmed by the microstructure; in many cases the oxides tend to fill up the pores.

Micrographs are included showing oxide inclusions in all coatings, and analytical values are quoted for oxide in copper deposits (which is the only one easily estimated). The lowest figure is 0.71% oxygen, representing 6.4% copper oxide, and in commercial work the figure is frequently half again as large. To obtain deposits low in oxide, use a slightly reducing flame and reduce the nozzle distance. Unfortunately, a pistol using a reducing flame is not working at its maximum efficiency. The practice of preheating the article advocated some ten years ago is now seen to be undesirable.

CREEP OF METAL

(Continued from page 280)

can be considered reliable only for the time range actually covered by the test.

2. As the stress is increased by arithmetical increments, the creep for any given time and temperature is increased by geometrical increments. For example, at 850° F. an increase in stress of 2500 psi. will, for any given time, approximately double the creep in 0.35% carbon cast steel. Cast carbon-molybdenum steel and forged 13% chromium steel require an increase of approximately 5400 psi. to double the creep.

3. As the temperature is increased by arithmetical increments, the creep for any given time and stress is increased by geometrical increments. For example, in the high temperature regions, an increase of 12° F. for any given time and stress will approximately double the creep in 0.35% carbon cast steel. (This influence of temperature is known with much less exactness than that of stress). The corresponding figures for cast carbon-molybdenum steel and low carbon, chromium steel are 22° F. and 48° F. respectively.

From the above it can be seen that the influence of temperature, especially in the region of 900 to 1000° F. is of utmost significance and any further advances in inlet steam temperatures must be considered seriously. For this reason, the cylinders for the high temperature turbines now under construction are made of carbon-molybdenum steel.

In addition to the studies of creep characteristics and their influence on turbine design, a great amount of development work in other lines has culminated in improved mechanical details which are certain to give better operation and greater reliability. Steam pipe strains are reduced to a minimum by casting the steam chest integrally with the cylinder cover. In rotor design, joints are avoided wherever possible. All of the high temperature machines have solid rotors. In condensing units, disks are shrunk on the rotor body to carry a part of the low pressure blading.

The latest practice in the mechanical construction of blading includes the use of shrouded blades throughout the machine. With this construction, the use of silver soldered lashing wires practically disappears. In the last two or three rows where lashing is still necessary, streamlined lashing welded to the blades is the standard practice.

The use of stellite shields welded to the inlet edges of the blades continues to be the most satisfactory method of reducing erosion of the low pressure blades. This construction is used wherever such protection is required.

MAGNETIC ALLOYS

(Continued from p. 284) All the alloys discussed in this paper received this heat treatment before any of the more special processes were applied.

(2) *Quenching* consists of heating the alloys for a short time at 600° C. (1110° F.), and cooling in air at room temperature for small samples with large surfaces, and in oil for larger samples. The rate of cooling is approximately 10° C. per sec.

(3) *Baking* consists of heating the alloys for 24 hr. at 425° C. (800° F.) and then slowly cooling to room temperature.

The data sheet (page 285) contains a table of typical compositions of several of the useful alloys, and their important magnetic constants. Three diagrams also show their magnetization curves for low, medium and high magnetizing forces. It may be seen from these curves that the permalloy group reaches almost saturation values long before the iron and silicon steel and the other alloys have reached the lower bend in the magnetization curve. With the exception of the 45 permalloy, which saturates at a fairly high value, the permalloys have low saturation induction and permendur the highest. The permeability curves computed from these curves are also plotted in two additional figures, and a series of "butterfly curves" at the right of the data sheet show the permeability curves for alternating current of small constant amplitude as a function of superposed direct current magnetizing force. In most communication apparatus this curve must be relatively flat over the expected range of direct current excitation.

Permalloy — Results of a survey of the iron-nickel binary system are also shown. The "permalloy region" includes alloys between 30 and 95% nickel. It should be noted that the large changes in the coercive force and the resistivity are at the lower end of the permalloy region, while the highest permeabilities are developed in the alloys containing between 75 and 80% nickel.

When other metals are added to permalloys their properties are changed. We found that a minor amount of chromium or molybdenum to a 78.5% permalloy produced a very desirable combination of high resistivity and high initial permeability. One of the diagrams on page 285

shows some of the properties of these alloys, either as quenched or as annealed. Several of these alloys have been developed for commercial use. Of these the most important are 2-80 Cr-permalloy, 3.8-78.5 Cr-permalloy, and 3.8-78.5 Mo-permalloy.

Perminvar — The distinctive magnetic properties of the perminvars are constancy of permeability at low flux densities, a low hysteresis loss in the same range, and, for medium flux densities, a characteristic constriction in the middle of the hysteresis loop. In some alloys this constriction is so extreme that the coercive force vanishes, making the two branches of the loop coincide when the magnetizing force is reduced to zero, in spite of the considerable hysteresis loss involved in the entire cycle. At high flux densities this constriction disappears and the loops have normal shapes.

Permendur — typically 50% iron and 50% cobalt — has high permeability, "enduring" to higher flux densities than other magnetic materials. It also has a relatively flat "butterfly curve." Difficulties in rolling and fabrication are overcome by 1.7% vanadium, which affects the magnetic properties only slightly.

Commercial Applications — One of the first uses of the permalloys (1921) was for continuous loading of a telegraph cable between New York and the Azores. For this project 78.5 permalloy was used in the form of 0.006-in. tape wrapped helically on a stranded copper conductor. The average initial permeability of this alloy in the laid cable was 2300, considerably less than can be obtained under the best conditions of heat treatment and absence of strains. However, even with this loading, the speed of transmitting messages was increased fivefold. By the time a second cable project was undertaken, the chromium permalloys had been developed, and 2-80 Cr-permalloy was selected, and the increase in permeability and in resistivity improved materially the message carrying capacity.

The largest use of permalloys in the telephone plant has been in cores of loading coils, where the alloy is used in the form of compressed insulated dust. For a high grade loading coil core made from iron dust the effective core permeability at low flux densities had to be limited to 33. The first permalloy used for loading coil cores was 80 permalloy, and the insulated and compressed core was designed for an effective permeability of 75. It is expected that the new *(Continued on page 328)*

MAGNETIC ALLOYS

(Starts on page 284) material containing molybdenum will have a permeability substantially higher than the 80 permalloy and that it will have intrinsically superior eddy current and hysteresis loss characteristics.

In d.c. apparatus where high permeability and low coercivity are of importance, and where high resistivity does not add to the usefulness of the core material, 78.5 permalloy is suitable. It is used in certain relay structures, usually of marginal types, in which the difference between operating and releasing currents is small.

For audio transformers, for retardation coils, and for other apparatus in which high permeability and high specific resistance must be combined, both 3.8-78.5 Cr-permalloy and 3.8-80 Mo-permalloy have been used. The former has slightly higher resistivity, but the latter has higher initial permeability and is more ductile.

The magnetic characteristics of the perminvars make them especially suitable for use in circuit elements in which the distortion and energy loss must be a minimized; but their relatively high cost, and the advisability of avoiding high magnetization throughout the life of the apparatus, have prevented their extensive use in telephone plant. One use for which perminvar is especially suitable is the loading of long submarine telephone cables. Here a high resistivity is very desirable, which has been shown to be obtainable in the 7-45-25 Mo-perminvar.

Permendur is used for cores and pole pieces in loud speakers, certain telephone receivers, light valves, and similar apparatus.

It may be seen from this survey that there is a great variety of magnetic materials with widely different properties from which an engineer may choose in designing magnetic elements in which magnetic flux changes are essential. Already these alloys have an important place in telephone plant. However, iron and silicon steel still are used extensively, and will continue to hold their own on a cost basis for some purposes. There is no doubt, however, that alloys of iron, nickel, and cobalt will continue to supplant iron and silicon steel in many places where circuits are redesigned to take full advantage of their magnetic properties.